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CONDITIONS COVERING THE INSTALLATION OF LEAD SERVICE PIPE

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Conditions under which service pipe is installed and used have changed considerably in recent years. They have placed an added burden on service pipe materials. Pressures in many cases have been stepped up, new types of fixture have increased water hammer, more services are installed under paved streets, and pavements are of more expensive and permanent types. Heavier traffic has increased vibration; movement and settlement are magnified by excavations and filled ground; the maze of pipes and cables has increased ground obstructions; and wider use of electricity means more stray currents with which to contend. Great strides have been made in water treatment. And, in addition, there are new service pipe materials with which to work.

Much has been written and said of these newer materials and how they are affected by modern conditions. This is as it should be, since all materials should be thoroughly examined both when first introduced and repeatedly as experience is gained with their use. It seems wise, therefore, not to forget the older materials and to review their selection, installation and use from time to time in the light of experience with them under changed modern conditions. How have higher pressures, water treatment, wider use of electricity and other factors affected their choice and the manner of installing them? Since lead is one of the oldest service pipe materials, it is often taken as a matter of course. I don't recall seeing any discussion of the use of lead services in waterworks annals in recent years except in those isolated cases where some trouble has arisen. Yet many cities use lead services today; some of our largest use them exclusively. For that reason, I feel that a review of how well lead pipe meets modern conditions in service pipe work is timely.

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Characteristics of Lead Pipe. Let us first consider the pipe itself. Small amounts of impurities can change appreciably the properties of lead. For instance, there are certain alloys of lead in use today with properties quite different from lead but that contain only a few one-hundredths of one per cent of alloying elements. Many impurities both harden and make lead more brittle. Some noticeably reduce its corrosion resistance. Under some conditions, lead harder than the ordinary is desirable, but for the average service pipe installation, the metal should be relatively soft and flexible. After all, permanent flexibility is one of the most important reasons for selecting lead service pipe, so that ground movement from heavy traffic and settlement can be readily taken up without strain at all times.

With this in mind, about three years ago the Lead Industries Association adopted rigid standards covering the quality of lead pipe. From the accumulated experience of many years, it was decided to limit the zinc content to 0.002%, as zinc is a particularly harmful impurity in lead. The minimum pure lead content of pipe was established at 99.7%. This means that all impurities combined, including zinc, cannot exceed 0.3% under the Lead Industries' standard. No individual limits were placed on the other impurities, as it was felt that the combined limit restricted them to a point where they would not be harmful in pipe.

Those are the requirements for the composition of good lead pipe, but mechanical requirements are equally important. This is particularly true of wall thickness. There are three classes of lead service pipe, classified according to wall thickness, known as A, AA and AAA in the East, and strong, extra strong, and double extra strong in the West. A and strong are identical, as are AA and extra strong, and AAA and double extra strong. Prior to 1932, these classifications had no direct relation to the pressures that might be used in the pipe. AA had a thicker wall and was consequently stronger than the same size A, and AAA had a thicker wall and greater strength than the same size AA. But 2-in. diameter AA was not as strong as 1-in. diameter AA, and so on. In other words, in the larger sizes, the wall thickness did not increase sufficiently over that of the smaller sizes to give them equal strength.

As a result, at the beginning of 1932, the industry revised the wall thickness of the larger service pipes so that all A or strong pipe would stand a constant cold-water pressure of at least 50 lb. per sq. in., all AA or extra strong would stand at least 75 lb. and all AAA

or double extra strong at least 100 lb., regardless of the diameter of the pipe. This greatly simplifies the selection of pipe of adequate wall thickness for the pressure involved. If working pressures are below 50 lb., you can safely use A or strong, if between 50 and 75 lb., AA or extra strong, and if between 75 and 100 lb., AAA or double extra strong, as shown in Table 1.

TABLE 1—CLASSIFICATION OF LEAD SERVICE PIPE

Classification East	Classification West	For Pressures up to lb. per sq. in.	Inside Diameter in.	Weight per Foot lb.	Weight per Foot oz.
A	S	50	¾	3	—
			1	4	—
			1¼	4	12
			1½	6	8
			2	8	12
AA	XS	75	¾	3	8
			1	4	12
			1¼	6	—
			1½	8	—
			2	13	12
AAA	XXS	100	¾	4	12
			1	6	—
			1¼	7	12
			1½	11	4
			2	19	8

In calculating these new wall thicknesses, the strength of lead was taken as 200 lb. per sq. in. That is the creep strength, not the ultimate tensile strength, which is over 1700 lb. per sq. in. Therefore, on a quick test, there is a factor of safety of between 8 and 9 under the new standard. That the new wall thicknesses have been conservatively reached is evidenced by the fact that not one pressure break of the new standard pipe used with the pressure for which it was designed has been brought to the Association's attention in the seven years since the new standard was adopted.

I emphasize this because a few water works engineers have expressed the opinion that even the new wall thicknesses are not adequate in the larger sizes and continue to specify one classification of lead pipe in the smaller sizes and a heavier classification in the larger sizes. That is now unnecessary. The reverse is true, that some of the smaller sizes will handle higher pressures than those for

which they are listed. That is because it is not practical, for mechanical reasons, to reduce the wall thicknesses of the smaller sizes still further. I would like to point out that in some of the larger sizes, the new standard weights in this country run as much as 50% higher than those used in Great Britain. Certainly they are adequate.

Correct wall thickness, of course, can only be effective if the wall thickness is uniform. A pipe may contain plenty of metal also, that is, be the correct weight per foot, but the bore may be off center and the wall too thin on one side. That, obviously, would lead to trouble even without excessive pressure, so the industry's standard takes this into account. It permits a tolerance of only 0.008 in. below the listed wall thickness of the pipe taken at any point on the pipe. There are other mechanical factors resulting from the manufacturing methods used, but I won't take time to go into them in detail here. Suffice it to say that pipe having pressed joints, dross inclusions, laminations and other undesirable characteristics is prohibited by the industry's standard.

We feel that the industry's standard has brought remarkable improvement in the quality of lead pipe in the last few years. Incidentally it has been adopted by New York and other cities in their purchases of lead pipe. It has at the same time simplified the water works engineer's problem of selecting the proper lead pipe. A further simplification of his problem has been made by the Lead Industries' Seal of Approval. The Association has licensed manufacturers to stamp this seal on pipe that meets its standard and makes regular inspections of material so stamped. Now all that it is necessary for a water works engineer to do to be sure of getting the right lead pipe for his conditions is to determine from Table 1 the correct class to specify, depending upon the pressure, and to insist on the seal on the pipe.

Those are the conditions within the pipe itself that govern the selection of lead service pipe. It can readily be seen that those internal conditions can be controlled.

Corrosion of Lead Pipe. We now come to the more complicated external conditions, some of which can not be controlled and some of which can. There are three principal types of attack on service pipe: soil corrosion, electrolytic corrosion, and solution by water. Lead may be affected by all three, but the degree is important. Practically complete control may be exercised over solution by water, partial control over electrolytic corrosion, and little control over soil cor-

rosion. Therefore, the latter two are most important in selecting pipe.

In a general way, lead pipe may be said to be affected by types of soils in the following order: muck, cinders, sand and clay, muck being most corrosive. Usually organic matter increases and good drainage decreases the rate of corrosion. There are other factors that may enter into the picture and modify expected results. For instance, tidal marsh might be expected to be highly corrosive to lead, but as K. H. Logan of the U. S. Bureau of Standards has pointed out, it is not, probably due to the presence of sulphates. Certain salts in the soil may thus form highly insoluble protective coatings on lead pipe, preventing attack after the initial period. Chlorides, bicarbonates and, particularly sulphides are among these inhibitors. In fact, under most conditions, the rate of soil corrosion of lead is small to begin with and is greatly reduced with the passage of time.

There is another factor in soil corrosion and that is local pitting. In many soils, corrosion of almost any metal is accompanied by this condition. In evaluating its importance, we must remember two things: first, the thickness of the pipe wall exposed to the condition, and second, whether pitting always continues at the same rate. Fortunately in the case of lead, the importance of pitting can usually be minimized because the walls of the pipe are unusually thick and because pitting, like general corrosion of lead, is greatly retarded by time in most soils.

In modern cities, we also frequently encounter many artificially induced soil conditions that should be considered. For instance, there may be cinder fill, highly corrosive to most common metals, and where lead services must pass through it, the metal should be protected. The same holds true where large amounts of free lime may occur in the soil. In the neighborhood of certain types of factories, chemical waste matter may contaminate the soil. Since lead is more highly resistant to a wider variety of chemicals than most metals, this need not present a problem unless the condition is acute. But if corrosive chemicals occur in the soil in any large degree of concentration, they will shorten the life of even a lead service, and protective measures should be taken. Protective measures against cinders, lime and other substances will be discussed later.

Another factor that affects rate of soil corrosion is particle size of the soil. Burns and Salley[1] of the Bell Telephone Laboratories

[1]*Particle Size as a Factor in the Corrosion of Lead by Soils*, by R. M. Burns and D. J. Salley, Industrial and Engineering Chemistry, March, 1930.

have shown that within certain limits corrosion increases as particle size increases. Yet another factor that affects the rate of soil corrosion is the purity of the metal itself. In general, the work of Logan at the Bureau of Standards indicated that impurities in the lead increase corrosion. However, since the Lead Industries' standard prescribes a relatively pure metal, use of that standard removes this as a problem for all practical purposes.

When we come to electrolytic corrosion, we arrive at something of ever-growing importance in recent years. More and more electricity is being used. More wires are grounded to pipes. More stray currents are found in the ground. Pipes must carry a current themselves and this current must leave the pipe at some point in order to have electrolytic corrosion take place. The question of grounding to water pipes is being studied thoroughly by the water works profession and I won't go into that. All service pipes being conductors, if wires are grounded to them, current will flow in them and there will be danger of electrolysis. You have the same problem here with lead pipe that you have with any other service pipe although the degree may not be so great because of the unusually thick lead pipe wall.

But when we consider stray currents in the ground, the problem is different, and we must consider it of very great and growing importance as the use of electricity increases daily. In this case, the current is not applied directly to the pipe, but the pipe must pick up the current from the ground. Now there are two ways to prevent or reduce damage from this source. One obvious way is to insulate the pipe by wrapping, by placing it in a pitch-filled trough, or by other means. This, of course, is a small added expense, but, I think, well justified if currents are known to exist in appreciable amount in the vicinity of the pipe.

The other way is through the use of a pipe which is itself a poor conductor of electricity. A poor conductor will naturally have less tendency to pick up these stray currents in the ground. Among the metals, lead is a relatively poor conductor (taking copper's conductivity as 100, lead's is less than 8.) Therefore, lead services are not very apt to pick up the stray currents, and if they aren't picked up, no such corrosion can result.

I don't mean to imply that it is impossible for lead to be destroyed by stray currents in the ground. If they are known to exist in quantity, the protective measures already mentioned are worthwhile. What I do want to get across is that the effects of stray cur-

rents are minimized when lead services are used. This has been recognized by many water works men. For example, as far back as 1932, the Engineering Department of the city of Minneapolis sent a letter to all plumbers in that city stating that tests and experiments they had made had shown that lead was by far the longest lasting service pipe material where electrolysis existed and ordering its use where there were car tracks or where electrolysis was known to exist. They further recommended wrapping, as previously mentioned.

One other thing should be remembered that is probably a contributing factor. That is, electrolysis is characterized by local pitting. Naturally a service with thick walls, such as lead services have resists perforation by these pits for the longest possible time.

Soil and electrolytic corrosion act on the outside of the pipe. Some protective measures can be taken against them, but it is not possible actually to change the nature of the soil or do away with stray currents in the ground. Therefore, these two types of external corrosion must weigh heavily in the selection of service pipe material.

There is a third form of corrosion, equally or more important in some cases, but which can be controlled. It is the action of the water in the pipe upon the metal of which the pipe is made. We all know that, judging by usual solubility standards, lead is highly insoluble even in aggressive water and that it usually forms a coating on its surface of even more insoluble compounds. By that I mean that no waters attack it to a point where corrosion would cause such troubles as failure or clogging of the pipe, or discoloration or bad taste in the water.

But ever since lead was first used in water supply systems many years ago, care has had to be taken to make certain that it was not used in installations where the lead might be dissolved in excessive amounts to produce illness. Plumbo-solvency has been a subject of almost exhaustive research in this country and abroad, and fortunately all this research and study has resulted in good knowledge of what may happen and how to meet the situation.

Admittedly, the easiest answer to the question of plumbo-solvency is to do away with the use of lead services altogether. In fact, that is the action sometimes taken. However, even if that is the easiest answer, it is not the best nor complete solution, because waters that attack lead sufficiently to cause danger will attack other common metals as well. Substitution of another metal for lead with aggressive waters may simply introduce other problems troublesome to the home

owner and water works engineer, such as short service life, discoloration, clogging or amounts of other metals in the water higher than recognized permissible limits. Also most cities already have many feet of lead service pipe in the ground. If there are economic reasons for using lead, which there must be since it is used so extensively, the answer cannot be in discontinuing its use. That would be like doing away with the automobile because there are so many automobile accidents, or with electricity because it frequently causes accidents or fires. The answer is to use these things properly.

Up to a few years ago, the notion was generally prevalent that regardless of the amount of lead taken in by the body, it gradually accumulated until ultimately lead poisoning resulted. The work of Aub, Kehoe, Fairhall and other recognized authorities on this subject has shown beyond doubt that the body has means of effectively disposing of small quantities of lead.

Kehoe, in one of his studies,[2] reports the result of an investigation he conducted in Mexico in a primitive Indian community, away from contact with lead and other metals. His investigation disclosed that the Mexicans were steadily excreting quantities of lead although having no apparent contact with it. Kehoe followed up this work with investigations in the United States among industrial workers, showing that exposure to varying amounts of lead resulted in correspondingly varying rates of elimination.

Thus Kehoe has shown that people are always exposed to some lead. Yet Barth[3] showed by analyzing the bones of young and old people that accumulation of lead throughout a lifetime is extremely slight. Therefore, it is fair to assume from this and other similar observations that lead taken in by mouth in usual quantities existent in our civilization does not result in abnormal accumulation. This is apparently due to the fact that the body can excrete the usual small quantities of lead as fast as they are ingested. Even a relatively greater amount of lead may be ingested once without harm if not repeated.

This type of modern medical research has, therefore, dispelled the notion that even small quantities of lead are cumulative when taken into the system. When all is said and done, the fact remains that lead is a common constituent of the earth's crust, and it is quite reasonable to suppose that over millions of years the human body has

[2] *On the Normal Absorption and Excretion of Lead*, Robert A. Kehoe, Frederick Thamann, and Jacob Cholak, Journal of Industrial Hygiene, 15, 5, Sept. 1933; *Normal Absorption and Excretion of Lead*, same authors, Journal of the American Medical Association, 104, Jan. 12, 1935.

[3] *Investigation of the Lead Content of Human Bones*, by E. Barth, Virchows Arch. f. Path. Anat., 281, 146, 1931.

been able to adjust itself to the presence of the metal in the ordinary contacts of daily life. Medical authorities are constantly adding to our knowledge of lead absorption.

All this research, together with practical experience in a number of communities, indicates that the U. S. Treasury limit of 0.1 p.p.m. lead in water is a decidedly safe limit. It further proves that should a consumer, due to unusual circumstances, ingest a relatively larger amount of lead at one time, which is not repeated regularly, his body can dispose of it without injury. In fact, recent work of Fairhall and Neal[4] of the U. S. Public Health Service has shown that lead arsenate, which is far more toxic than lead, can be ingested in amounts as large as 10 milligrams per day for 10 days and that 85% of it is eliminated from the human system within a few days.

Fortunately, there are only a few water supplies in the United States where water is sufficiently aggressive to make the use of lead, without some protective measures, undesirable. This is evidenced by the fact that millions and millions of people are drinking water every day, without harm, that has passed through lead pipes.

Since a change to another material does not solve the problem and since the characteristics of lead are frequently needed to take care of conditions like soil and electrolytic corrosion and settlement that are virtually otherwise beyond control, how can lead pipe be used safely in those few cases where the water is unsuited to lead pipe? One answer is to use lead pipe with a block tin lining, not a thin coating but a substantial lining. The other is to treat the water. In this connection, I would like to quote from a paper written by Robert Spurr Weston in 1935. He said, "Galvanizing protects iron for a while, but in many waters, the zinc dissolves rapidly, bringing 'red water' troubles in its wake. Waters which so affect zinc may be carried in pipes of yellow brass, red brass, copper and lead, but even these corrode in certain waters. The escape from corrosion by choice of pipe metals being barred, treatment with chemicals may be employed."

The work of Weston and others has conclusively proved the feasibility of treatment in a number of actual cases, some of which have previously been cited before this Association. To name one or two, there were the Milford-Hopedale and the recent North Attleboro cases in Massachusetts, in both of which localities absolutely safe corrective measures were taken.

[4]*Experiments on the Absorption and Excretion of Lead Arsenate*, by L. T. Fairhall and P. A. Neal, Public Health Reports, U. S. Treasury Dept., 53, No. 29, July 22, 1938.

No definite rule can be laid down as to the waters that will dissolve excessive amounts of lead since there are several variables. We can say from experience and our knowledge of the nature of public water supplies, that only a very small percentage of them will take excessive amounts into solution. For instance, an investigation by the Massachusetts State Board of Health some years ago showed cases of lead poisoning in only 4 out of 300 municipalities supplied in whole or in part through lead services. Yet this was in New England where most of the unsuitable waters are located. I am speaking of public supplies only. There may be private supplies from springs or wells elsewhere that should not be delivered through lead without treatment. We can safely say, however, that there is little if any danger in the United States from public supplies outside New England.

In a general way, very soft waters attack lead sufficiently to require protective measures. We can't judge by the pH value alone, as some waters with a very low pH value are less corrosive than others with a higher pH because of different compositions. High oxygen and free CO_2 content and low hardness add to the corrosiveness of the water, and certain salts in the water are inhibitors. Likewise stable organic matter in waters that might otherwise be corrosive may deposit on the pipe walls, forming an adherent protective coating that prevents solution of lead by the water. On the other hand, soft waters from peaty moorland sources contain organic acids, in addition to carbonic acid, which increase the attack and do not form protective coatings.

Where we have waters with a low pH value, high oxygen and CO_2 content, and hardness below 50 or 100 p.p.m., lead services should be used with care. As previously stated, such waters in a public supply are rare, but where they must be handled, either tin-lined lead or treatment following laboratory study should be employed. These waters may be successfully treated, as has been proved in a number of cases, with such substances as lime or sodium silicate or a combination of them. In this way, aggressive waters may be made safe and we can avail ourselves of the desirable qualities of lead without danger. Chlorine in the amounts usually employed in water systems seems to have no noticeable effect on the solubility of lead, according to H. F. Whitaker, of the National Research Council,[5] and other authorities.

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[5]*Research Information Surveys on Corrosion of Metals*, No. 6, compiled by H. F. Whitaker, National Research Council, Washington, D. C., 1924.

Summing up briefly what I have said with regard to the three common types of service pipe corrosion: soil conditions and electrolysis are difficult to control, but water conditions can be adequately controlled at reasonable cost. Since a change of pipe material does not help solve the water problem, the external factors should be given greatest weight in selecting a pipe material, and then water treatment used where necessary.

Installation of Lead Pipe. The mechanical installation of lead pipe itself may also have great bearing on the performance of the pipe. There are ground movement, vibration and settlement in practically every service pipe location, yet occasionally lead service pipe is installed without a goose-neck. That is wrong. A goose-neck adds only a little to the length of pipe needed and with lead can be bent right into the pipe without making an extra joint. So it costs little to put a goose-neck in a lead service and make adequate provision for settlement. In fact, with long services, say 100 ft, or more, it is well to put a second small goose-neck in the pipe where it enters the foundation wall. This one need not be as large or pronounced as the one at the main, but simply a slight gradual curve.

Goose-neck sizes should vary with the diameter and wall thickness of the pipe. For instance, they should range from 2 ft. of pipe in the goose-neck for 1 in. and smaller AA pipe, to 6 ft. in the goose-neck for 2 in. AAA. The dimensions I have given are taken along the curved line of the pipe. Table 2 gives the approximate size of goose-neck for various sizes and weights of pipe.

TABLE 2—SIZE OF LEAD GOOSE-NECKS

Inside Diameter of Pipe in.	AA (XS)		AAA (XXS)	
	Length of Pipe in Goose-Neck ft.	Straight Length Goose-Neck ft.	Length of Pipe in Goose-Neck ft.	Straight Length of Goose-Neck ft.
Up to and including				
1	2	1¼	2½	1½
1¼	2½	1½	3	1⅞
1½	3	1⅞	4	2½
2	4	2½	6	3¾

The larger goose-necks for larger and thicker-walled pipe are to prevent thinning the pipe wall on the outside of the bend and distortion of the pipe's cross-section.

It helps to insure a proper goose-neck if the corporation cock has a tail-piece bent at a 90-degree angle so that the tail-piece parallels the main. Then the pipe has to start off in that direction and be bent around to its ultimate direction, at least forming part of the goose-neck. The goose-neck should, however, have a reverse bend to form a question mark. The goose-neck should preferably lie in a horizontal position to the right when facing the main.

Sometimes, tappings are taken off the top of the main. This should be avoided, if possible, but when it is done, the goose-neck should be formed in the same way. Blocking, however, should be placed between the top of the main and section of goose-neck above it just beyond the joint. In case of settlement, this will relieve strain on the joint and tapping will allow it to be taken up in the goose-neck. On long services or those in particularly bad ground, the pipe may be left slightly wavy to take up settlement all along the line. Both these waves and regular goose-necks should lie almost horizontally to prevent trapping if the pipe is drained.

Lead is a soft metal and should be handled accordingly to get the best results with it. For instance, if the bottom of the trench contains rocks or stones that might damage the lead, fine soil or sand should be filled in the trench bottom before laying the pipe. Similarly it is wise to back-fill for at least 6 in. with soil or sand free from rocks so that the pipe is protected all around. I have already mentioned that where electrolysis is known to exist or where the soil contains much free lime or where the pipe passes through cinder fill, the pipe should be wrapped or laid in a trough filled with pitch. Protection should also be afforded lead pipe where it is bedded in green cement.

A cast-iron sleeve should be provided where lead passes through the foundation wall, the joint being made water-tight by calking with lead wool.

Possibility of water hammer in modern piping systems brings up another installation question. Pressure surges many times the magnitude of the constant pressure in the pipes may develop by certain types of valves or defective valves. Piping systems should be protected against these momentary pressure surges if conditions are such that they are liable to occur. If the service pipe is of lead, it may in time yield to the excessive pressure and finally burst. It will act like a fuse. If there is no lead pipe in the system, the condition will sooner or later result in leaky joints and immediately in annoying knocking, pounding and damaging vibration in the pipes.

Reporting on a water hammer condition that had caused a lead service to break in a large distillery, Henry Pommerenck and A. A. Kalinske of the University of Wisconsin, working under F. M. Dawson, wrote, "It seems that the lead pipe acted as a sort of 'safety fuse'; its breaking has indicated the presence of high water hammer pressures, which, if allowed to continue, would eventually have caused other parts of the system to fail." They further state, "The solution to this whole problem is to correct the development of excessive water hammer pressures. . . ."

The answer then is to control or eliminate water hammer, not merely to resist it. It is not my province here to discuss fully the water hammer question, as many systems require special study. Suffice it to say that in ordinary cases, air chambers of correct size installed at proper points and with provision for replacing air that leaks out or dissolves will do the job of control. Elimination may frequently be accomplished by replacing quick-closing valves with valves that operate more slowly or by repairing defective valves.

In the installation of lead service pipe, joints have been successfully made by wiping, cupping and soldering, and by means of compression-type couplings. I, personally, believe that no joint can be made in any kind of service line equal to a properly made wiped joint, which is peculiar to lead pipe only and is most generally used with it. However, the other kinds of joints have been employed successfully in a number of cities. Incidentally, it is usually possible to make up the wiped joints on the bench in the shop. This is a great time and money saver and insures the best kind of joint, because working conditions are ideal.

This brings up a brief discussion of cost. Nobody should use lead services if they care only about low first cost. There are other materials that cost less per foot. But the water works engineer is interested in cost over a period of years, and that is only indirectly affected by first cost. The known long life of lead services distributes the slightly higher first cost over a great many years and makes the annual cost low. I say slightly higher first cost, because I believe that when costs are analyzed it is found that lead does not cost much more. In first cost must be included not only the material but the cost of opening the pavement, trenching, laying the pipe, the fittings, back-filling, repaving and other items that makes the pipe material cost only a small percentage of the total. And all those costs are repeated if the material does not stand up.

Summary. To summarize what I have said of the modern conditions covering the installation of lead service pipe:

1. Lead pipe is now made under rigid quality standards.
2. Pipe made to these standards is readily identified by the Lead Industries' Seal of Approval.
3. This seal and standard make it easy to select lead pipe for any given pressure conditions.
4. The new wall thicknesses are more than adequate for the pressures usually encountered.
5. In general, lead pipe is resistant to soil corrosion, muck and cinders being most corrosive.
6. Usually the rate of corrosion is reduced with the passage of time.
7. The thick walls of lead pipe are an added life factor both in relation to general corrosion and pitting.
8. Lead being a poor electrical conductor is not apt to pick up stray currents in the ground.
9. Certain waters, mainly soft waters high in CO_2 and oxygen, and found, in the United States, principally in New England, dissolve sufficient lead to make it inadvisable to use lead to conduct them for domestic purposes without protection.
10. Since these waters also affect other metals adversely, and since external corrosion and other factors often make the use of lead highly desirable, the answer is not a change of pipe material but to treat the water or to use lead pipe with block tin lining.
11. Economical water treatments have been developed that, if used, make lead suitable for the conveyance of any water with which we have yet had to contend.
12. Water hammer is destructive to any piping system. If lead pipe forms a part of the system, it will yield first, as a "safety fuse," but in any event, systems should be protected against water hammer.
13. Either the cause of water hammer should be corrected by replacing quick-closing valves or repairing defective valves, or air chambers or other protective devices should be installed.
14. Adequate goose-necks should be provided.
15. Lead pipe should be laid in fine dirt, free from rocks, protected by wrapping or pitch-filled troughs where certain corrosive conditions are known to exist and should pass through an iron sleeve in the foundation wall.
16. Wiped joints are preferable, but other types are satisfactory.

17. Joints should be made up in the shop wherever possible for better work and lower costs.

18. The first cost of lead services is higher than that of some other materials but not much higher, as the cost of material is only part of the first installation cost.

19. Because the life of lead services is known to be long, the annual cost is low.

COMPARATIVE STUDIES OF LACTOSE-BROTH AND BRILLIANT-GREEN-BILE, AT CAMBRIDGE, MASS.

BY FRED E. SMITH*

[*Read December 21, 1939.*]

Many culture media have been critically tested in connection with the bacteriological examination of water samples. In most cases, the object has been the possible development of a medium that would be specific for coliform organisms; also to eliminate the many false presumptive tests that occur in the standard procedure using lactose broth. It is probable that brilliant-green-bile has received most attention. Hale (1) favors the use of brilliant-green-bile for primary inoculation and accepts the results of the presumptive tests as definitely positive or negative. Jordan (2) has reported the results of studies conducted by a group of laboratories that experimented with brilliant-green-bile as a direct inoculum and also as a confirmatory medium. It was found that 2% brilliant-green-bile, when used as a primary medium, yielded 80.5% of the completions obtained by the standard procedure. As a confirmatory medium, brilliant-green-bile confirmed the presence of coliform organisms in 95% of the samples that were confirmed by the standard procedure. The same author (3) has compiled a most interesting history of the development of brilliant-green-bile. Butterfield (4) has further examined the results of the studies reported by Jordan and tends to oppose the use of brilliant-green-bile as a primary medium. This author also advises that the use of brilliant-green-bile as a confirmatory medium should be restricted to waters that are proved to yield results comparable with those obtained with the standard procedure. McCrady (5) has published the results obtained by another group of collaborating laboratories. In his excellent presentation, brilliant-green-bile is regarded favorably as a confirmatory medium.

In the eighth edition of *Standard Methods of Water Analysis* the parallel-planting procedure advanced by Jordan (3) is listed as a non-standard method for water-purification control tests. The confirmatory procedures presented in this volume for further examination of positive lactose-broth tubes list brilliant-green-bile as one of the four liquid media.

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The present studies were instituted in order to determine the applicability of 2% brilliant-green-bile to the bacteriological examination of Cambridge water. The medium was examined first in the rôle of a *direct inoculum,* and lactose-broth was used in parallel tests as the standard procedure. The second part of the work consisted of the use of brilliant-green-bile as a *confirmatory medium* in parallel with the use of the eosine-methylene-blue plate and additional procedures. The studies extended over a period of 15 months. Parallel inoculation of both media was not practiced continuously throughout the period, but a sufficient number of samples was examined to indicate the extent of usefulness of brilliant-green-bile in filtration-plant control. Parallel confirmation of all positive, lactose-broth, presumptive tubes was performed during the entire period.

Samples. Routine laboratory practice at Cambridge includes the bacteriological examination of four samples daily. These are collected from the raw, coagulated, filtered, and chlorinated-effluent waters. The raw water comes from impounded sources, and the bacterial content, generally, is not high. The coagulated water, following dosage with alum, is subjected to sedimentation for a period of 2 hours. Water passes through the filters at a rate of 130 m.g.d. per acre. The effluent water is dosed with lime for corrective treatment and is chlorinated at the rate of 2 lb. per m.g. The period of contact between the effluent water and chlorine is indefinite, varying from 1 to 9 hours; residual chlorine tests average 0.06 to 0.1 p.p.m. Table 1 presents data compiled from monthly averages of analyses during the period of these studies.

TABLE 1.—AVERAGE ANALYSES OF CAMBRIDGE WATER.

Sample	Color p.p.m.	Alkalinity p.p.m.	pH	CO_2 p.p.m.	Bacteria per c.c. Agar	Bacteria per c.c. Gelatine	Indicated Number of organisms per 100 c.c.
Raw	43	19.0	6.8	3.5	49	109	66.0
Coagulated	35	9.0	5.9	13.0	28	88	6.2
Filtered	4	9.0	5.9	—	15	33	0.42
Effluent	4	23.0	8.7	0	1	1	0.11

Procedure. Using the decimal dilution method, brilliant-green-bile and lactose-broth tubes were inoculated with appropriate volumes of each sample. All tubes were examined whenever possible at the

end of 24 hours of incubation, and confirmatory procedures were applied at that time to tubes containing gas. At the end of 48 hours of incubation, the tubes were removed, and gas production was recorded.

All primary tubes that contained gas were confirmed, irrespective of the volume of gas produced. Eosine-methylene-blue plates were streaked from positive lactose-broth and brilliant-green-bile primary tubes. When the plates were removed after incubation, the growth on the plates was examined according to Levine's (6) classification of coliform growths on this medium. If characteristic coliform growth was present, or no growth at all, the plates were discarded, and the confirmatory results were recorded as positive or negative. However, if atypical colonies were present on the confirmatory plates, these were fished and transplanted into secondary lactose-broth tubes and agar slants for further study. In addition all presumptive lactose-broth tubes that produced gas were re-inoculated into secondary brilliant-green-bile tubes. If gas was produced in 48 hours, a positive confirmatory result was recorded; if no gas was produced, the result was recorded as negative.

It is seen that of the two methods of confirmation of positive lactose-broth primary tubes one consists of a single re-inoculation into brilliant-green-bile and is based upon the production or non-production of gas in this medium. The other confirmatory method uses the eosine-methylene-blue plate and, if necessary, supplementary procedures. When this schedule of confirmatory tests is compared with those described in other published work, it will be noted that all positive presumptive tubes were not carried through to the completed test. The method was adopted of confirming primary tubes through the several procedures until a definite positive or negative result was obtained. If error was introduced in this manner, the direction was toward a greater number of positive results, and plant operation was accordingly adjusted. For instance, if coliform growth on an eosine-methylene-blue plate was recorded as a positive result without further study in a secondary lactose-broth tube and under the microscope, the possibility of proving the test to be negative under later procedures was omitted.

It was desired to experiment with brilliant-green-bile according to a schedule of laboratory tests for filtration plant control; hence, in accordance with routine practice this shortened procedure was used.

Results of Direct Studies. The results obtained in the compara-

tive studies of brilliant-green-bile and lactose-broth as primary media are presented in Table 2.

TABLE 2.—RESULTS OF PARALLEL EXAMINATIONS OF SAMPLES IN BRILLIANT-GREEN-BILE AND LACTOSE-BROTH AS PRIMARY MEDIA.

	No. of samples examined	No. of samples positive with lactose-broth	Per cent of total	No. of samples positive with brilliant-green-bile	Per cent of total
Raw	200	121	60.5	132	66
Coagulated	200	67	33.5	48	24
Filtered	113	3	2.7	0	0
Effluent	150	4	2.7	0	0

Examination of 200 raw-water samples with both media indicated that coliform organisms were present in 121 samples, or in 60.5% of all samples, according to the standard procedure. Brilliant-green-bile yielded positive tests in 132 samples, or 66% of the total number examined. The increase in positive results of 5.5%, by the use of brilliant-green-bile, is a favorable consideration, not only because of the greater number of positive tests, but also because the brilliant-green-bile primary results were definite. Throughout these studies, every positive brilliant-green-bile tube that was used as a primary medium produced characteristic coliform growth when subjected to confirmation on eosine-methylene-blue agar. That is, the positive results that were obtained with brilliant-green-bile on primary inoculation could have been so recorded without further study.

Inspection of the results obtained with coagulated-water samples shows a different condition. Lactose-broth yielded 67 positive tests, or 33.5% of the total, while brilliant-green-bile produced 48 positive tests of 24% of the 200 coagulated-water samples examined by means of both media. The difference between the two figures is not great: 9.5%. The trend toward lower brilliant-green-bile results is continued in the data referring to the filtered and chlorinated-effluent samples. In the examination of 113 filtered and 150 effluent samples, coliform organisms were indicated by lactose-broth in 3 and 4 samples respectively. No positive tests were produced with filtered and effluent samples by brilliant-green-bile. These results are in accordance with those obtained by other observers in that brilliant-green-bile

appears to be somewhat inhibitive when used for treated or chlorinated waters.

Results of Confirmatory Studies. Table 3 presents the results of parallel confirmation of positive lactose-broth primary tubes.

TABLE 3.—RESULTS OF PARALLEL CONFIRMATION OF LACTOSE-BROTH POSITIVE TUBES.

Samples	No. of tubes inoculated	No. of tubes positive	Confirmation			
			Brilliant-green-bile secondary tube	Per cent of total positive	Eosine-methylene-blue plate; lactose-broth tubes; microscopic	Per cent of total positive
Raw	208	141	125	88.7	123	87.2
Coagulated	207	119	61	51.3	65	54.6
Filtered	319	25	16	64.0	16	64.0
Effluent	1675	64	20	31.3	20	31.3

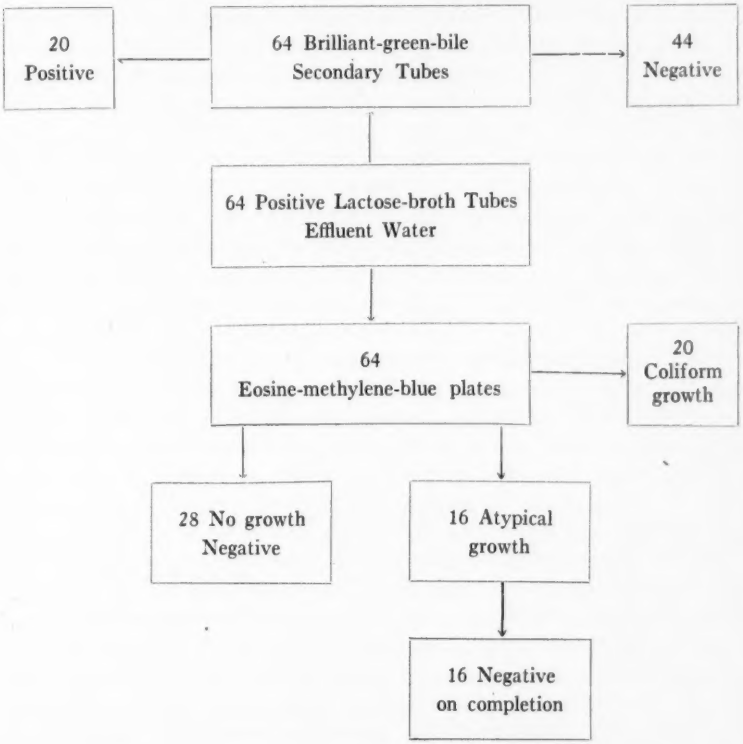
With raw-water samples, 141 positive lactose-broth primary tubes were obtained. Of these 125, or 88.7%, were confirmed in brilliant-green-bile secondary tubes, confirmation being indicated by the presence of gas in the medium. There were 123 confirmations of raw-water tubes, or 87.2%, when the second method of confirmation was used, consisting of eosine-methylene-blue plates followed if necessary by other tests.

The high degree of correlation between the two methods of confirmation continues in the data for coagulated-water samples. With these samples many unconfirmed presumptive tubes were obtained. Nearly 50% of the presumptive tubes for coagulated water failed to confirm, compared with approximately 12% of the raw-water tubes. It is difficult to assign reasons for the failure of the coagulated-water tubes to confirm. The water has been treated with alum preparatory to filtration, and some bacteria have been eliminated as is shown in Table 1 by the plate counts on agar and gelatine. The low pH of the coagulated water may have an adverse effect upon coliform organisms in the water. The condition illustrated by the results of confirmation of coagulated-water samples represents a serious disadvantage in the use of lactose-broth, namely the failure of confirmation of many primary tubes.

When the filtered and effluent presumptive tubes are considered, it is apparent that, although the data referring to these samples are

not extensive, the high degree of correlation between the two methods of confirmation is continued. This fact can also be illustrated schematically. The data were obtained in the confirmatory tests applied to the 64 positive effluent tubes.

PARALLEL CONFIRMATION OF 64 LACTOSE-BROTH PRIMARY TUBES



The conclusion may be drawn that the use of brilliant-green-bile as a confirmatory medium is well suited to the positive primary tubes produced by Cambridge water irrespective of the source of the sample. The brilliant-green-bile procedure has the added feature of a greatly simplified technique. The question of typical or atypical colonies on the eosine-methylene-blue plate does not arise, and the selection of colonies for further study is eliminated. Finally, should more in-

formation concerning bacterial growths be desired, the secondary brilliant-green-bile tube, which produced gas in the confirmatory test, may be used for further studies.

Discussion. During these studies the object was to examine a procedure of detection of coliform organisms that would be applicable to laboratory control of water purification. In most plant laboratories, confirmation of positive tubes obtained from waters in process of purification extends only to a secondary liquid medium or to the eosine-methylene-blue plate; and the completed test is not performed on presumptives obtained from finished waters by all plant laboratories.

For these studies there were available four types of water, each differing considerably from the others in many characteristics. The untreated raw water contained a bacterial flora that decreased in number during the passage of the water through the filtration plant. Also, the studies extended over a sufficient period of time so that seasonal effects upon the bacterial content, if any, could manifest themselves.

In water purification control, the information afforded by the bacteriological examination of plant samples must be accurate and should be obtained in the shortest possible time after collection of the samples. The use of the brilliant-green-bile in the examination of Cambridge water fulfills both of these conditions. It has been previously stated that every brilliant-green-bile tube that produced gas in the presumptive test confirmed on the eosine-methylene-blue plate. This observation also indicates that the results of brilliant-green-bile primary tests may be definitely recorded within 48 hours after collection of the samples, without further study. Using the standard procedure with lactose-broth, it is possible that the schedule of tests may be prolonged several days before the final result is obtained. Assume, for instance, that a plant sample produced gas in lactose-broth in 48 hours. Further, assume that the eosine-methylene-blue confirmatory plate yielded atypical colonies. Inoculation of secondary lactose-broth tubes might require 48 hours for gas production. The elapsed time is 5 days, a period during which the water has passed through the distribution system. The results of the extended study are useful as a matter of record only.

The fact that the positive brilliant-green-bile presumptives definitely indicate the presence of coliform organisms is of value especially with reference to the raw water. If after 24 hours of incubation

the raw-water sample produces gas in brilliant-green-bile, the laboratory can make use of this information by ordering any necessary changes in the application of chemicals for the water treatment. The medium in this manner is most useful in water-purification control.

It is a fact that brilliant-green-bile failed to detect 9.5% of the coagulated-water samples that were indicated to be positive by lactose-broth; the corresponding figure is 2.7% for both filtered and effluent waters. From the standpoint of safety, a medium used in bacteriological control tests should not possess inhibitive powers. Hence, the following question arises: should a medium be rejected because of the small numerical discrepancies recorded, even though its use presents advantages that are of great value in the water examination required for filtration plant control?

It is well known that lactose-broth has certain disadvantages; false presumptives entail additional work in the laboratory, and confirmatory tests require days before the final results are ascertained. Investigators have proved that the standard procedure is by no means 100% effective in the detection of coliform organisms. On the other hand, brilliant-green-bile yields definite positive or negative results with Cambridge water within 48 hours after collection of the sample. Finally, in any bacteriological study, it is practically impossible to obtain 100% correlation between the results of comparative tests because of conditions inherent in the work itself, irrespective of the merits of each individual medium.

The possibility exists that brilliant-green-bile is selective in its applicability to waters in different sections of this country. This may account for the divergent results reported by observers and is considered by some to represent a definite objection to the acceptance of brilliant-green-bile as a standard medium. Water supplies are "rugged individuals" with respect to methods of purification, and in similar manner the bacterial flora of water supplies may be capable of exerting selectivity in the culture media used in water examination.

"Standard Methods of Water Analysis" has placed the results of water examinations, chemical and bacteriological, upon a comparable basis. To depart from the methods outlined is a serious responsibility. As these studies have indicated a slightly inhibitive effect of brilliant-green-bile in the examination of treated and chlorinated samples in Cambridge, lactose-broth is continued in use as the primary medium. Brilliant-green-bile is used in all routine confirmations of lactose-broth presumptive tubes in this laboratory without further

study, except with occasional samples; and the results indicated by the brilliant-green-bile secondary tube are recorded as definitely positive or negative.

Conclusions. Comparative studies of brilliant-green-bile and lactose-broth in the examination of Cambridge water have proved that the newer medium may be used satisfactorily with raw-water samples as a direct inoculum. It is slightly inhibitive for coagulated, filtered, and chlorinated waters. As a confirmatory medium, brilliant-green-bile shows a high degree of correlation with the results obtained with eosine-methylene-blue plates and subsequent tests.

The development of a medium that would have specific application to the detection of coliform organisms is greatly needed in water examination. The present standard procedure requires excessive time and demands skillful technique in its application to water examination. The standard method is not infallible in the detection of coliform organisms. Even though the standard method has been in use for many years—and with beneficial results to all consumers—this fact should not prevent critical study and evaluation of its usefulness now when other media, including brilliant-green-bile, are available to water laboratories.

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SODIUM HEXAMETAPHOSPHATE AS AN AID IN THE CONTROL OF CORROSION

BY OWEN RICE*

[*Read September 12, 1939.*]

That the addition of one or two parts per million of sodium hexametaphosphate to water will prevent the precipitation of calcium carbonate, as disclosed by Rosenstein (1), is now generally recognized. This process has been called "threshold treatment" because the presence of the hexametaphosphate seems to stop the growth of crystal nuclei on the "threshold" of crystallization. This effect is believed to be due to the adsorption of a very thin film of metaphosphate on the nuclei which effectively prevents further precipitation upon them. That the threshold treatment of water with sodium hexametaphosphate should reduce the rate of corrosion of iron in contact with water may be surprising, but it is understandable when one realizes that this substance is strongly adsorbed, not only on substances such as calcium carbonate, but also on metals and metal oxides.

Most of you have already read some of the papers that have been published dealing with the effect of threshold treatment in preventing the precipitation of calcium carbonate (2, 3, 4, 5). We are going to review briefly some of these data because they show very clearly that the hexametaphosphate is adsorbed from solution on calcium carbonate. This discussion will give us a better understanding of the fundamental mechanism of threshold treatment and so of its effect in the control of corrosion.

If a water supersaturated with calcium carbonate is passed through a bed of filter sand or through a municipal distribution system, some precipitation of calcium carbonate will occur. In order to determine the effect of threshold treatment on this reaction in the laboratory, the plant conditions were duplicated by running a supersaturated solution through a glass tube containing 200 grams of filter sand encrusted with a coating of calcium carbonate. In the absence of metaphosphate, about 30 p.p.m. of calcium carbonate were precipitated. After the addition of 2 p.p.m. of metaphosphate to this same water, the precipitation progressively decreased; indeed, after 10

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liters of water had passed through the sand, precipitation had ceased entirely. These results are shown in Figure 1. Similar results were

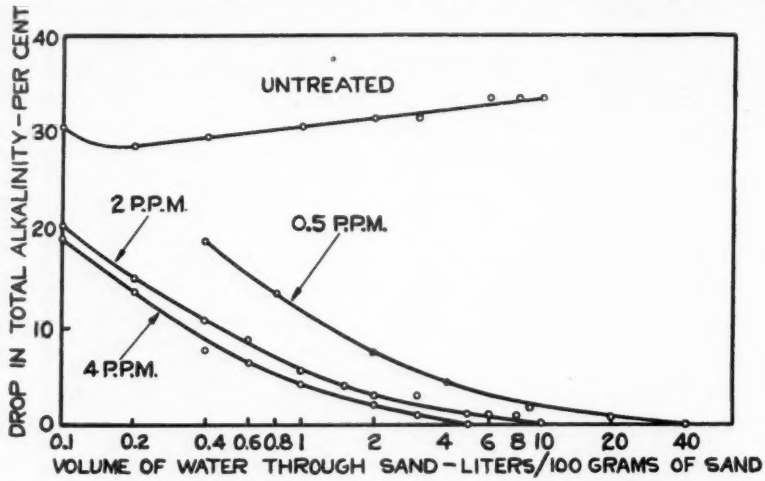

FIG. 1.—THRESHOLD TREATMENT WITH SODIUM HEXAMETAPHOSPHATE REDUCES AFTER-PRECIPITATION TO ZERO.

obtained with 1 p.p m. and with 0.5 p.p.m. of metaphosphate present in the water, the only difference being that 20 and 40 liters of water had to be passed through the sand before precipitation was entirely prevented. It seems evident to us that, if the metaphosphate worked only on the calcium carbonate in solution in the supersaturated water, the first portion of water passing through the tube after the addition of the metaphosphate would have shown no precipitation. That such was not the case and that it was also necessary to coat the surface of the filter sand with a film, perhaps only of molecular dimensions, seems to us to be clearly indicated by the fact that a volume of water varying inversely with the amount of metaphosphate present has to pass over the sand before precipitation is entirely prevented. Further evidence on this point was obtained by running an additional amount of this same water, to which no metaphosphate had been added, through the filter sand which had been, shall we say, invisibly coated with the metaphosphate in the previous experiment. It was found that almost a reverse of this curve was obtained and that it was necessary to run a considerable volume of water through the sand before precipitation started again.

Another experiment which sheds additional light on the mechanism of this effect is the addition of 200 p.p.m. of sodium carbonate to a water of approximately 200-p.p.m. hardness (as $CaCO_3$) and determining the pH at frequent intervals. Curves similar to those shown in Figure 2 will be obtained. Precipitation begins almost immedi-

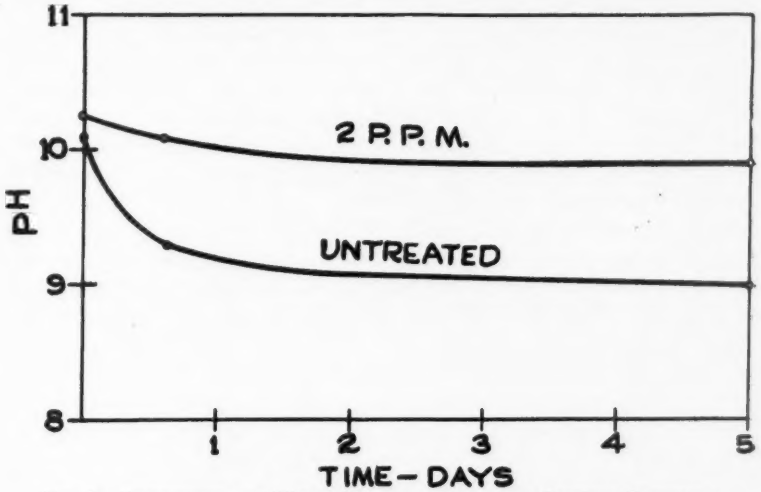

FIG. 2.—STABILIZATION OF WATER SUPERSATURATED WITH CALCIUM CARBONATE AS INDICATED BY pH.

ately, of course, in the sample to which no metaphosphate has been added and becomes visible within five minutes. The pH drops rapidly during the first few hours and then slowly during the following days. The sample to which 2 p.p.m. of hexametaphosphate have been added will contain no visible precipitate even at the end of five days, but we wish to point out that there is a slight drop in the pH of the solution. We can only explain this drop in pH by assuming that a small amount of calcium carbonate has been removed from solution. On the other hand, there is no visible precipitate, nor does the water show a Tyndall cone. From this, we would assume that the precipitate of calcium carbonate was of extremely small particle-size, indeed, of dimensions below the wave-length of light. Our explanation, then, of the effect of one or two parts per million of sodium hexametaphosphate in preventing the precipitation of calcium carbonate is that the metaphosphate is adsorbed on the

surface of calcium carbonate crystal nuclei before they grow to a visible size; that this adsorbed film of metaphosphate is sufficient to prevent the further growth of the crystals; and, consequently, that we have in effect a stabilization of a supersaturated condition with respect to calcium carbonate.

Many municipal water plants have already started the use of sodium hexametaphosphate in amounts varying from 0.5 to 2 p.p.m. Most of these plants are softening plants that were initially interested in preventing the precipitation of calcium carbonate. This result has been obtained in all cases, but what is of more interest to you, and what has proved to be of more interest to them, is that almost from the day on which the treatment was started complaints of "red water" decreased, and there has since been little or no red water either in the mains or in the domestic hot-water systems.

Since, as mentioned before, sodium hexametaphosphate is adsorbed on iron and iron oxide, on copper and copper oxide, as well as on other metals, it is not hard to conceive that this adsorbed film might decrease the rate of corrosion of the metal. That this adsorbed film does have this ability to decrease the rate of attack of oxygen on iron may be easily shown and, since experiment is more convincing than argument, the means of testing this effect given below is proposed. In making laboratory experiments on the rate of corrosion of iron and steel, it is usually found that oxygen determinations give the best quantitative estimate of the amount of corrosion actually occurring. Because of the large surface presented and its convenient form, steel wool offers a suitable material for such tests. In Figure 3 is shown a sketch of a laboratory setup that has been found to be well adapted to making tests of this kind.

The vertical riser tubes permit the water to run through the sample of steel wool at a constant rate, and the increase in the head of the water in the tubes serves as a measure of the oxidation of the iron and the consequent plugging of the steel wool with the oxide. If the water were run through the steel wool under constant pressure there would be a constantly decreasing flow of water through the sample which would introduce another variable.

The mixing bottle insures thorough mixing of the water with the sodium hexametaphosphate or other solutions that are being fed and also gives time for the small air bubbles that are entrapped by the water falling through the vertical tubes to become separated. A small stopper, with a vertical hole running to horizontal holes bored

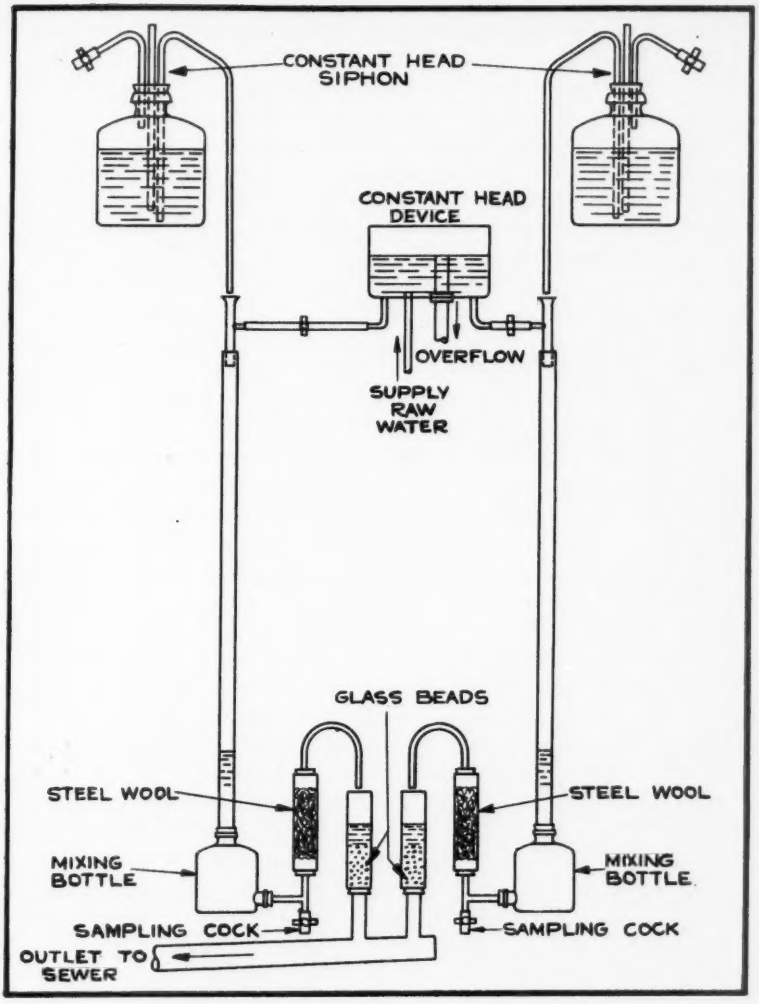

FIG. 3.—LABORATORY APPARATUS FOR TESTING EFFECT OF THRESHOLD TREATMENT IN MINIMIZING CORROSION.

through it, placed in the lower end of the riser tubes, provides a baffle and aids in separating the air bubbles from the water.

The sampling cocks shown permit samples of the water to be taken in order that determination of the oxygen and iron content may be made before as well as after passage through the steel wool.

Allowing the water to flow over glass beads, after passage through the steel wool, offers a convenient means of showing the effect of threshold amounts of sodium hexametaphosphate in preventing the precipitation of dissolved iron from the water. This is a point that we shall discuss later.

The constant-head siphons that are shown have been found to be sufficiently accurate feeding devices. It is advisable, however, to have at least an 8-in. head on the siphon and to depend on a length of capillary tubing in the delivery line to regulate the flow of solution. Because of possible error due to larger dilutions, it is advisable not to use solution feeds below 4 ml. per minute.

In making tests on the effect of sodium hexametaphosphate on corrosion, it is necessary to keep in mind that this effect is due to the adsorption of metaphosphate on the surfaces with which the water comes in contact. Consequently, a considerable quantity of water containing the metaphosphate must be brought in contact with the surface before this adsorbed film develops maximum protection. In general, just as we saw to be the case with the filter-sand experiment previously described, the higher the concentration of sodium hexametaphosphate in the water being passed through the apparatus, the smaller the amount of water that must be used in order to reach a minimum rate of corrosion. If only one or two parts per million of sodium hexametaphosphate are present in the water, it will be found that the amount of oxygen absorbed by the steel wool will drop with time, but that the rate of decrease is so slow that several hundred hours will be required for it to reach a minimum. This is satisfactory in the plant but too long for laboratory tests. By using a higher feed of sodium hexametaphosphate, the surface of the steel wool will become coated in a much shorter period of time and the oxygen absorbed will decrease quite rapidly. Because of this fact, it is desirable to start with a feed of sodium hexametaphosphate of 10 to 20 p.p.m. and then, after a period that has been found long enough to saturate the surface, to drop the feed of metaphosphate to 1 or 2 p.p.m. in order to determine the minimum feed that is sufficient to maintain the protective film.

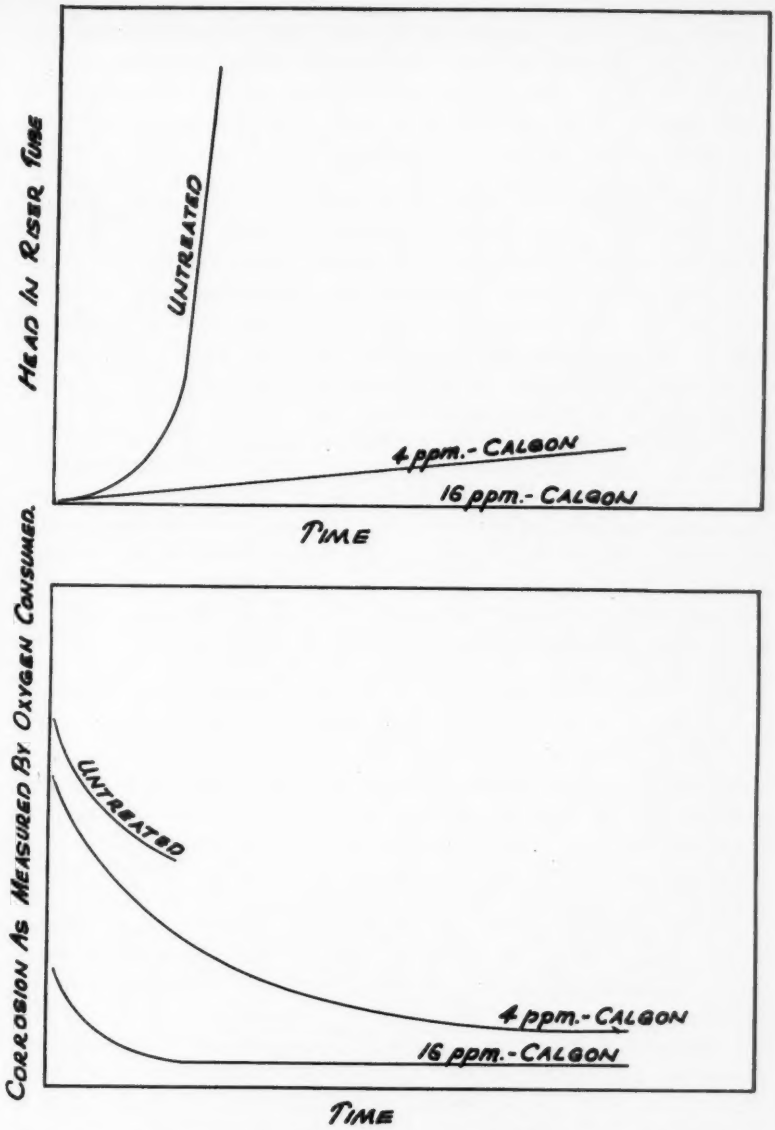

FIG. 4.—EFFECT OF THRESHOLD TREATMENT IN REDUCING CORROSION, AS MEASURED BY HEAD OF WATER AND OXYGEN CONSUMED BY STEEL WOOL.

Tests of this type, using about 500 ml. of water per minute through 20 grams of coarse (No. 3) steel wool, have shown that approximately one day is required at 10 p.p.m. and five hours at 20 p.p.m. in order to thoroughly saturate the surface. Curves typical of those obtained by tests of this nature are shown in Figure 4.

While determinations of the oxygen absorbed show that corrosion is not entirely prevented, it is clearly evident from these tests that sodium hexametaphosphate in threshold amounts is very effective in minimizing corrosion even under the condition of large specific surface in this accelerated test. Oxygen determinations on many municipal water systems have shown that the oxygen loss is much less than that which takes place under the conditions of this test. In view of this, it is not unreasonable to expect that exceedingly good results will be obtained in municipal water systems by a feed of metaphosphate of the order of 1 p.p.m.

We mentioned earlier that metaphosphate would prevent the discoloration of the glass beads shown in the experimental apparatus. This is another manifestation of the adsorption property of sodium hexametaphosphate which we believe makes it outstanding in the control of corrosion and red water. We mentioned earlier that sodium hexametaphosphate is adsorbed on the surface of metals, their oxides and salts. Just as in the case of calcium carbonate, the adsorbed film of metaphosphate which forms on the surface of nuclei of hydrated ferrous oxide tends to prevent further oxidation and precipitation of the iron as hydrated ferric oxide. Our work has indicated that from 3 to 5 times as much metaphosphate as iron must be present if such precipitation is to be entirely prevented. In other words, a water containing about 0.25 p.p.m. of iron will remain clear and free from color, even on continued exposure to air, if 1 p.p.m of sodium hexametaphosphate is also present. If the water contains 0.5 p.p.m. of iron, it would be necessary to have about 2 p.p.m. of metaphosphate present in order to prevent oxidation and precipitation of the iron. This is a particularly important effect in the treatment of municipal water supplies, since, in most cases, water works operators are even more concerned with a decrease in red water than a decrease in corrosion.

From these experiments it is evident that sodium hexametaphosphate, when present in water in very small amounts, not only decreases corrosion and consequently the amount of iron going into solution but also prevents the discoloration of the water from the

oxidation and precipitation of the small amount of iron that does go into solution.

It has been brought rather forcefully to our attention that some of the most severe cases of red water result not so much from corrosion as from the accumulation of a precipitate of iron oxide in the mains and services that is dislodged at times of high demand. It seems evident to us that threshold treatment, by greatly reducing the precipitation of iron in the mains will minimize, if not eliminate, such complaints. It is evident that when red water is caused by dissolved iron present in the water, the addition of alkali is not only not a remedy but will possibly aggravate the condition since the increase in alkalinity would tend to precipitate the iron.

Because of the double action of sodium hexametaphosphate, threshold treatment appears as a most promising means of decreasing corrosion and preventing complaints from red water. The adsorption of the metaphosphate on the surface of copper, and lead, as well as iron and steel, also seems to form a protective film that decreases the corrosion of these metals, but this is still being investigated.

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AN APPRAISAL OF P.W.A. AND W.P.A. WATER SUPPLY WORK IN NEW ENGLAND

BY WILLIAM W. BRUSH*

[*Read September 13, 1939.*]

In the field of public works construction, the United States government has set up two agencies to stimulate construction, thereby decreasing unemployment and increasing business activity especially in the so-called heavy industries. These agencies are generally designated respectively as P.W.A. and W.P.A. P.W.A. stood for Federal Emergency Administration of Public Work of which Secretary of the Interior, Harold L. Ickes, was Administrator. P.W.A. was organized in 1935 and superseded earlier similar activities started in 1933, and when referred to will include these earlier agencies. W.P.A. was up to recently, the Works Progress Administration of which Harry L. Hopkins was Administrator and which was organized in the latter part of 1935, taking over functions of earlier relief agencies.

After Congress passed the Reorganization Act of 1939, the President created the Federal Works Agency with John M. Carmody as Administrator. This agency was established about the beginning of July, and under it was placed P.W.A. with the title of Public Works Administration and Colonel E. W. Clark as Acting Commissioner. W.P.A. was included under the title Works Projects Administration with Colonel F. C. Harrington, Commissioner, Colonel Harrington having had charge of W.P.A. after the appointment of Mr. Hopkins as Secretary of Commerce. The Federal Works Agency also has placed under its charge the following organizations: Public Roads Administration, Public Buildings Administration and U. S. Housing Authority.

P.W.A. and W.P.A. have financially aided in carrying out both federal and non-federal public works projects. In this paper, we are concerned with the water supply projects that have been undertaken with the assistance of these two agencies. To avoid confusion, the two agencies will be discussed separately. P.W.A. has had the larger part in the water supply field, so will therefore be first taken up.

Public Works Administration. The P.W.A. work started in 1933,

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although the earlier work was carried out under a different organization. The basic principle underlying this work is the furnishing by the Federal Government of a grant to be applied toward the cost of constructing the public work in question, the state or political sub-division thereof furnishing the balance of the money necessary for the completion of the work. The grant has usually been 45% of the total estimated cost. The Federal Government also would make loans on proper security in the form of bonds to cover either the whole or a portion of the cost of the work not provided for by the grant. Subsequent to the early days of the activity, very little money has been obtained through loans, as the various public bodies interested found they could secure their own money at interest rates lower than the 4% rate that was usually charged on loans.

To obtain a P.W.A. grant, it was necessary that the sponsor who would have to be a state, city or other public body, submit a description of the project with a plan and estimated cost. If this project were approved both by the Administrator and by the President, the work was placed under contract by public letting, the terms of the specifications and plans being subject to the approval of the P.W.A. engineering staff. The work was then carried out under the direction of the local officials with the P.W.A. engineers inspecting the work to see that it was being done in accordance with the specifications and plans.

The selection of projects to be undertaken was based largely upon the value of the project to the community and the extent to which employment would be increased by the carrying out of the project.

Every authorization that has been made by Congress for P.W.A. work has been materially less than the estimated cost of all the projects submitted for Federal aid. The Federal Works Agency reports that it now has on hand projects that would cover approximately $1,000,000,000, for which no funds are available. The last session of Congress made no provision for additional funds for P.W.A. work, and this agency is therefore now carrying out the program that was initiated in 1938, and that is to be completed by the end of June, 1940.

The 1938 program was based upon the authorization made by Congress in that year for P.W.A. work. Under this program, New England water supply projects have been undertaken in 36 communities with a grant of practically $11,000,000. The total estimated cost of these projects is slightly over $24,000,000. By far the largest project in this program is that for a pressure aqueduct and appurtenances for the Metropolitan District Commission that serves water to Boston

and the surrounding suburban areas. For this project, the grant is $6,985,000, the estimated cost being $15,522,000.

Table 1 summarizes P.W.A. projects in New England in the 1938 program:

TABLE 1—P.W.A. WATER SUPPLY PROJECTS IN NEW ENGLAND INCLUDED IN THE 1938 PROGRAM.

State	No. of Communities	Grants	Total Estimated Cost
Connecticut	2	$ 372,000	$ 827,000
Maine	6	1,019,000	2,265,000
Massachusetts	19	8,397,000	18,660,000
New Hampshire	5	76,000	168,000
Rhode Island	4	1,121,000	2,489,000
Vermont	0	.....	.....
Totals	36	$10,985,000	$24,409,000

Including 1938 and all prior programs, the amounts alloted to water supply work in New England as of April 11, 1939 were in round figures as follows: Loans, $666,000; Grants, $14,047,000; Total estimated cost of projects, $33,457,000. These projects involved 111 communities.

The figures for each state are given in Table 2.

TABLE 2—P.W.A. WATER SUPPLY PROJECTS IN NEW ENGLAND INCLUDED IN THE 1938 PROGRAM AND EARLIER PROGRAMS

State	No. of Communities	Loan	Grant	Total Estimated Cost
Connecticut	6	.....	$ 826,000	$ 1,945,000
Maine	8	.....	1,174,000	2,680,000
Massachusetts	60	$142,000	10,292,000	24,129,000
New Hampshire	18	132,000	354,000	1,038,000
Rhode Island	11	233,000	1,285,000	3,119,000
Vermont	8	159,000	116,000	546,000
Totals	111	$666,000	$14,047,000	$33,457,000

The total water supply allotments that have been made under P.W.A. and earlier programs represent 2,691 water works projects, while the amount of Federal funds for carrying out these projects totals $207,074,000, of which $65,931,000 represent loans and $141,143,000

are grants. As has been previously noted, grants generally have been on the basis of 45% of the total estimated cost, which for all of these projects is $380,795,000, giving an average cost per project of $142,000.

The total P.W.A. funds for public works have amounted to about $6,000,000,000 with some 30% used for federal projects and the balance for non-federal projects.

To give an idea of the character of the water supply work carried out with Federal aid, this work has been placed under four heads and the percentage for each worked out on the basis of the number of projects and on the estimated cost. The resulting figures are given in Table 3.

TABLE 3—PERCENTAGE OF VARIOUS CLASSES OF WATER SUPPLY WORK BASED ON CONDITIONS AS OF NOVEMBER 30, 1938.

Class of Work	Projects	Estimated Cost
Complete water works	77	75
Reservoirs	8	9
Filtration plants	5	6
Water mains	10	10
	100	100

In an attempt to determine whether New England has received its fair proportion of the money alloted for water supply work in the entire United States, a comparison has been made on a population basis. The total population of the United States as shown by the 1930 census, including the forty-eight states and the District of Columbia, was 122,800,000. By the same census, the population of the six New England states amounted to 8,165,000 and represented 6.67% of the entire population. The P.W.A. grants for water supply in New England amount to $14,047,000, while the P.W.A. grants for water supply work in the entire United States amounted to $141,143,000. The New England grants represented 9.95% of the total. It would appear, therefore, that Federal aid for water supply projects in New England is equivalent to approximately 50% more than her population ratio would have entitled her to, had such a ratio been used.

Through the courtesy of Arthur D. Weston, Chief Engineer, and Francis H. Kingsbury, Senior Sanitary Engineer, Department of Public Health, Massachusetts, the breakdown of the water supply

P.W.A. work in that state can be made. This shows that, based upon the number of communities benefited, the extension of distribution mains takes first place, with new water systems a close second, followed by new treatment works. This breakdown is set forth in Table 4.

TABLE 4—SUMMARY OF P.W.A. WATER SUPPLY WORK IN MASSACHUSETTS.

Class of Work	Number of Communities Benefited	Amount of Grants	Estimated Cost
New water system	16	$1,016,000	$2,502,000
Additions to source of supply	5	231,000	632,000
Additions to supply conduits	2	7,390,000	16,423,000
New treatment works	10	411,000	1,013,000
Additions to treatment works	2	276,000	613,000
Extension of distribution mains	18	761,000	2,824,000
Additional distribution storage	7	158,000	280,000
Totals	60	$10,243,000	$24,287,000

Works Projects Administration. We will now consider the part that W.P.A. has taken in the water works field in New England. W.P.A. projects have been largely selected on a basis of the number of men who would be employed. This work is carried on by the Federal Government furnishing the labor and also furnishing generally approximately six to seven dollars for each man month of labor utilized. This money can be used to secure supplies, materials, or equipment. The sponsor must meet any additional cost that is required to carry out the project.

The general procedure of setting up a W.P.A. project is to have a description of the work with the necessary plans prepared and submitted by the sponsor which must be a state or political sub-division thereof, or other body recognized as one to whom Federal aid may be given. The project is then passed upon by the W.P.A. state organization and sent to the Administrator in Washington who in turn submits it to the Director of the Budget and the President. If the President approves the project, a limit is placed by him upon the amount of Federal money that may be utilized for the project. If it is later found that the project cannot be completed for the amount estimated, then an additional allotment may be made, if approval is given by the

President. Under the act, which was passed on June 30, 1939, providing $1,477,000,000 for W.P.A. work for the fiscal year ending June 30, 1940, the limit of Federal funds that can be spent on any single building is $52,000, but no monetary limit is placed on water supply projects. However, for projects undertaken after January 1, 1940, the sponsor must provide 25% of the total estimated cost of the project, including in such cost the labor to be furnished by W.P.A. Under previous W.P.A. authorizations, there were no similar financial limits.

Relatively, the amount of water supply work undertaken under W.P.A. has been much less than under P.W.A. Cost figures for W.P.A. individual projects are generally lacking, the cost being relatively very high due to the character of labor utilized and the conditions under which it is employed.

While an effort was made to obtain up-to-date figures on the water supply work undertaken in New England and throughout the United States by W.P.A., the writer was unable to obtain these figures in time to include them in his paper. He has, however, received from the Massachusetts State Department of Health statistics for W.P.A. undertakings in that state, which showed that such work has been carried out in 211 communities representing 678 projects. This work is covered almost entirely under the two headings of Extensions of Distribution and Improvement of Sources of Supply, with the distribution projects being nearly six times those of the improvement of sources of supply.

A summary of the water supply work in Massachusetts under W.P.A. is given in Table 5.

To give some idea of the W.P.A. expenditures in New England,

TABLE 5—WATER SUPPLY WORK IN MASSACHUSETTS UNDER W.P.A. COMPLETED OR NOW IN PROGRESS

Class of Work	No. of Communities	No. of Projects
New water works system	1	1
New treatment works	5	7
Additions to treatment works	3	4
Additional distribution storage	5	5
Improvement of sources of supply	59	95
Extension of distribution mains	138	566
Totals	211	678

figures reported by W.P.A. as of June 30, 1938, have been brought together. The total allocations of W.P.A. funds to the forty-eight states and the District of Columbia had amounted to, in round figures, $4,800,000,000, while $325,000,000 had been spent in the six New England states, or 7% of the total.

No figures are available for the amounts expended by W.P.A. on water supply work in the New England States. From the figures given, it would appear that the amounts allocated throughout the United States for water supply and some other activities, but mainly water supply, sum up to $154,000,000 or a little over 3% of the total. The greater part of the water supply work undertaken by W.P.A. has been in the distribution systems, and several thousand miles of mains have been laid with W.P.A. forces. Also, a substantial number of water treatment plants have been constructed, many hundred wells sunk and other water supply work carried out.

General Appraisal. The work actually conducted in the water supply field with Federal aid under the two public works agencies has been set forth as far as the data available permit. An appraisal of the value of this work, from the viewpoint of the health departments of the New England states has been secured. The representatives of health departments report that the undertaking of water supply improvements with Federal aid was encouraged by their departments, and that the work accomplished has been satisfactory in quality and generally in line with the financial resources of the communities within which and for which it was performed.

It is impossible to tell how much of this work would have been undertaken had Federal aid not been made available. In one state, it was estimated that, by using Federal aid, various water supply undertakings have been advanced in their completion by from five to ten years.

The writer believes that based upon the information furnished to him by engineers of the various state departments of health, a fair conclusion is that the P.W.A. and W.P.A. work in the water supply field of New England represents a valuable contribution to the majority of the communities receiving this aid.

The views of several of the consulting engineers in the New England area, as to the value of the water supply work undertaken with P.W.A. and W.P.A. aid, were also solicited. The replies received indicated similar views to those expressed by the engineers of health departments, it being noted, however, by the consulting engineers

that some of the activities, especially in laying mains to supply outlying areas and speculative developments, very probably will prove to represent work that was not sufficiently needed at the time to justify the expenditure required.

There has generally been comparatively little criticism of the way in which work has been carried on with P.W.A. aid. While some believe that, due to the red tape involved when Federal funds are utilized, the value of the grant made by the Federal Government was largely absorbed by the increased cost of the work and delay in completion of the work, it is generally recognized that the work under this Federal Agency has been carried out in a reasonably effective manner.

There has been a great deal of criticism of W.P.A. work, especially as to cost of the work and relative inefficiency of the forces employed. W.P.A. work has been carried on with the men engaged spending generally but one half of the time on the work, so that at least two separate gangs would be required each week on any job. Furthermore, the men employed were in many instances not physically able to perform effective work, and the supervision is reported to have been frequently of a character that would not develop efficiency.

The water supply work, when the labor costs are included, have frequently been several times what would be expected if the work were carried out under contract or by gangs regularly employed on such work instead of by relief labor.

A national appraisal committee was appointed to make a report on the work program of the Works Progress Administration, this committee representing the following bodies: American Engineering Council, American Institute of Architects, American Municipal Association, American Public Welfare Association, American Society of Planning Officials, National Recreation Association, U. S. Bureau of Public Roads, U. S. Conference of Mayors and Works Progress Administration. A report was submitted by this Committee dated April, 1939.

In the report it is stated that the appraisal covered forty-two states and that 7,737 surveys were analyzed. These surveys included 2,102 rural communities, 1,201 small cities, 266 middle-sized cities, and 154 large cities. Seventeen questions were asked, and the number of answers received to the various questions ranged from slightly over 1,000 to somewhat over 7,000.

It is believed that the following questions with the percentage of answers in the affirmative or favorable to W.P.A. work will be of interest:

1. Were the improvements and services badly needed?.....94%
2. Were they of benefit to the community? 97%
3. Has work relief maintained the skills of the projects' workers?.....82%
4. Has work relief maintained the employability of a project worker?.....80%
5. What has been the quality of the workmanship? (Good).....85%
6. Are the public facilities under the works program of permanent value?...90%
7. What has been the effect of the works program on the fiscal condition of governmental sub-divisions? (Favorable).....79%
8. Has the program developed long-range community planning?.....74%
9. Is work relief better than the dole for the community?.....93%

Now let us consider the future of P.W.A. and W.P.A. in the New England water works field. Federal Works Administrator John M. Carmody has started to return to public bodies 5,043 applications for public works projects, which were submitted but for which no money is available. These applications involve a request of grants amounting to $767,000,000 and loans amounting to $242,000,000. The total estimated cost for these 5,043 projects is estimated at $1,749,000,000. Comment is made by the Administrator that not all of these projects would have been approved had the money been available.

The estimated cost of the projects returned to the New England states is given in Table 6.

TABLE 6—NEW ENGLAND P.W.A. PROJECTS BEING RETURNED DUE TO LACK OF FUNDS, AS OF SEPTEMBER 1939.

State	No. of Projects	Estimated Cost
Connecticut	78	$24,895,000
Maine	21	1,744,000
Massachusetts	30	5,444,000
New Hampshire	13	2,631,000
Rhode Island	20	24,236,000
Vermont	7	640,000
	169	$59,590,000

There appears to be a comparatively small amount of P.W.A. water supply work pending in New England. An approximation of it is summarized in Table 7.

As to future W.P.A. work, it seems to be dependent largely upon the interest in a community in having such work undertaken by W.P.A.; the number of unemployed in the community or in the vicinity of the community and whether the water supply project involved would be approved by the W.P.A. authorities, including the President.

TABLE 7—SUMMARY OF PENDING P.W.A. WATER SUPPLY WORK IN NEW ENGLAND.

State	No. of Communities	Estimated Cost
Maine	2	$ 275,000
Massachusetts	7	2,139,000
New Hampshire	4	163,000
Rhode Island	1	189,000
Vermont	1	62,000
	15	$2,828,000

The state administrators for the New England area to whom application should be made for the approval of a W.P.A. water supply project, are as follows:

Connecticut: Vincent J. Sullivan, 125 Munson Street, New Haven, Connecticut.

Maine: John C. Fitzgerald, Congress Building, 142 High Street, Portland, Maine.

Massachusetts: John J. McDonough, 600 Washington Street, Boston, Massachusetts.

New Hampshire: William C. Fahey, Silver & Lincoln Streets, Manchester, New Hampshire.

Rhode Island: Farrell T. Coyle, 17 Clinton House Street, Providence, Rhode Island.

Vermont: Harold M. Baker, State Capitol, Montpelier, Vermont.

Summary: The investigation of P.W.A. and W.P.A. work in New England made by the writer has led him to the following conclusions:

1. Both P.W.A. and W.P.A. work in the New England area has resulted in improvement of numerous water supply systems including the building of needed systems.
2. The work performed has been generally both satisfactory in quality and needed.
3. There is a moderate amount of additional water supply work in New England that would probably be undertaken if Federal aid were available.
4. Until Congress authorizes additional funds for P.W.A., W. P. A. is the only Federal agency that can aid in the improvement or construction of water supply projects.

Discussion

Francis H. Kingsbury.* Mr. Brush's paper has dealt with the subject in a very comprehensive way, but I believe that it may be helpful if I make a few observations with regard to particular conditions in Massachusetts.

When the various Federal agencies were making funds available for the construction of public works, the Department of Public Health of Massachusetts communicated with the several cities and towns where it was felt that works for supplying water and providing sewerage were needed, calling their attention to the Federal agencies and recommending that these municipalities give consideration to submitting projects for sanitary works. The Department of Public Health in Massachusetts has encouraged the construction of new water supply systems, the extension of existing water supply systems and the improvement of existing water supply systems as Public Works Administration and Works Progress Administration projects, and it has been the experience of the Department that the undertaking of these much-needed projects has been for the most part satisfactorily performed. The water supply facilities in this state have been definitely improved with the funds made available through Federal agencies.

Projects have been undertaken in Massachusetts under the Public Works Administration estimated to cost in the aggregate about $24,000,000, and from information furnished by that administration the subdivision of these works may be shown in Table 8.

It will be noted that entirely new water works systems have been

Table 8—Summary of Public Water Supply Work in Massachusetts Under P.W.A.

Class of Project	Number	Loans	Grants	Estimated Cost
New waterworks system	17	$123,608	$ 1,016,461	$ 2,502,047
Additions to source of supply	5		230,696	632,310
Additions to supply conduits	4		7,390,350	16,423,000
New treatment works	10		411,338	1,012,912
Additions to treatment works	2		275,850	613,000
Extensions of distribution mains	19	18,000	760,588	2,824,479
Additional distribution storage	7		157,860	379,866
Total	64	$141,608	$10,243,143	$24,387,614

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installed in 17 communities not previously having public water supplies and that new water treatment works have been installed in 10 such communities under P.W.A. Other projects have provided for necessary additions to sources of supply, supply conduits, including the new pressure aqueduct of the Metropolitan Water District, additions to existing treatment works and improvements in distribution systems. An interesting comment on the table showing the projects of the Public Works Administration is that the total amount of loans made through the Federal Government is relatively small, showing, what most of us appreciate, that municipal borrowing through private agencies in Massachusetts has been upon a very favorable basis.

An examination of a list of projects undertaken by the Works Progress Administration shows that for the most part these projects dealt with work where heavy equipment was not necessary, and Table 5 will show that by far the greater number of projects undertaken under W.P.A. consisted in the installation of water mains. It can readily be appreciated that such work ordinarily requires very little equipment and lends itself to the employment of a greater amount of labor than is true in general of projects undertaken under P.W.A.

No cost figures are immediately available to permit a comparison of the volume of work undertaken under the Works Progress Administration in Massachusetts with work undertaken under the Public Works Administration.

Two large projects for new water treatment works built by the city of Leominster and the Salem and Beverly Water Supply Board under W.P.A. are particularly worthy of mention and illustrate the possibility of carrying out extensive projects under W.P.A. provided suitable supervision is available.

WARREN J. SCOTT.* One point that might be mentioned in connection with Mr. Brush's interesting appraisal of P.W.A. and W.P.A. water supply work in New England, is that of Connecticut's 107 public water supplies, approximately 80% numerically are owned by private companies. This naturally greatly lessens the utilization of Federal funds in our state. Another interesting fact is that the largest single water supply project in Connecticut during recent years is the addition to the water supply of the Hartford Metropolitan Area which has been undertaken without any allocation of Federal funds.

*Director, Bureau of Sanitary Engineering, Connecticut Department of Health, Hartford, Conn.

Following droughts in 1923 and 1924, when the adequacy of several public water supplies in Connecticut was threatened, extensive additions to many sources of supply were carried out. Two large supplies are being augmented by present construction, viz., those of Hartford and Bridgeport. By and large, with a few exceptions, our Connecticut water supplies are now well off from the standpoint of adequacy, looking ahead over a reasonable span of years.

The principal prospect for new water supply projects in our area is for construction of filtration plants, desired by the consumers primarily for improvement of physical quality of surface water supplies although incidentally desirable from the standpoint of safeguarding the supplies against contamination. As watershed populations grow, filtration plants will be useful weapons against increased hazards to surface water supplies. One of our recently constructed water filtration plants, the Willimantic plant, which the Association inspected this spring, was a well done W.P.A. project, although filtration plants generally fit in better with P.W.A. type of construction. I have no figures on the cost at Willimantic.

Extension of water mains into suburban areas and development of small village supplies in a few localities furnish some additional possibilities for water works construction. Strengthening of water distribution systems by additional feeders or storage, and replacement of small pipes, are probably needed on the majority of water systems, even though there is no great demand for them among the uninformed general public. Education of the public along these lines and perhaps in some cases the awakening of the water works fraternity are necessary.

Mr. Brush's figures indicate that New England proportionately obtained more than her share of P.W.A. water works funds, based on population comparisons. When one stops to analyze this, one explanation may be that more people proportionately in the New England area are served by public water supplies than in the country as a whole.

THEO J. LAFRENIERE.* Your President informed me that you might wish to know what had been done in the Province of Quebec to relieve unemployment. This question is a very delicate one just at present, as the provincial and federal authorities do not agree on the subject, the divergence of opinion extending also in the political field.

Canada is a Federation of Provinces, similar to the Union of the

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American States, and it was felt that the federal government should share with the province the burden of helping the municipalities with the problem created by the crash of 1929. Our central government has the right to impose many taxes, so it was expected that its resources could be called upon to help in the matter. If you have read the Montreal *Gazette* this morning, you have been informed that tea in Canada will cost 10 cents a pound more, because we are at war. Of course there will be no Tea Party because we have much representation and more taxation (Laughter).

An agreement was adopted in 1930, by which municipalities could undertake public works and obtain one-third of the cost from the provincial government and also a similar amount from the federal government. The works had to be done during the winter months, as it was considered that it was the period during which help was most needed by the unemployed. The result was that most municipalities wanted to get their 66⅔ cents, and in doing work during the winter months which is a difficult season here, few actually got real value, even for the share of municipal monies spent.

Other agreements were passed between the Quebec and Ottawa governments, the latter providing 25% of the cost, and the former executing the works. Later, this was changed to a 50-50 basis on certain projects, but the money had to go in wages but not in material, with the result that we are probably, at the present time, the province best supplied with swimming pools, parks and even baseball grounds. Some of that money could have been spent to better advantage in the construction of water purification works, because we still need some of them.

Both governments have subsidized road works; especially a transcontinental highway is under construction because so much can be done with a shovel (hand shovel) and requiring a minimum of material. Bridges have also been built, but the government of the province had to supply the cement and steel, the stone being quarried locally.

For a time the government of Quebec felt that public works were too costly and resorted to direct relief, which meant that municipalities could place the families without work on a dole system, according to a certain schedule. The municipality could also require work from the men on the dole, but it had to supply the materials of construction, as the governments were contributing 80% of the amount of direct relief, the balance being provided by the municipal authorities. The

amount of work obtained from the men under relief was never great, and rather discouraging in certain districts.

During the last three years in this province, $34,000,000 have been spent on direct relief and $43,000,000 on public works, making a total of $77,000,000 for a population of 3,300,000. Of course some of that money could have been spent to better advantage, so is it felt by those who have to secure sanitary improvements to public works.

Now, last spring our federal government came up with a new system, by which it was placing at the disposal of the province the sum of nine million dollars to be loaned at the rate of 2%, for revenue-producing works which included water and sewerage works. Unhappily, the government of this province as well as the government of the Province of Ontario refused to participate in the agreement. They claimed that it was too costly, and that the municipalities would have a hard time to carry on even if they took the money at 2%. The main reason was this: The federal government had required that the provincial governments guarantee the reimbursement of interest and sinking fund, and our provincial government did not want to accept such responsibilities, although it had the right to select the municipalities that could profit by the loan. Therefore we have nine million dollars at the disposal of this province to carry on public works which will not be used this year, I am afraid. (Three million dollars are now available to cities and towns since the change in the provincial government.)

To cope with the situation, considering that the province did not want to accept that system of 2%, the federal government agreed to pay again 40% of either direct relief or public works that the province would undertake; the other 40% being supplied by the province, and the municipality furnishing 20% which had to include the cost of administration. I might say that in the last two months public works have been practically at a standstill in this province and "we have gone on direct relief".

You may have read in the papers that a British Commission is coming here with plenty of money, and that some $500,000,000 will be spent on munition works. We hope that it is so and that unemployment and relief will disappear, because it is high time that it should disappear. The municipalities are carrying on with difficulty under the present stress, and they are looking more and more to the government for help, either provincial or federal, because they have reached, in many cases, practically their borrowing limits.

FEDERAL CONSTRUCTION SUBSIDIES FOR SMALL PUBLIC WATER SUPPLIES

BY SAMUEL M. ELLSWORTH*

[*Read December 21, 1939.*]

It is the purpose of this brief paper to bring before you some of the problems that face a small town when it comes to consider the construction of a public water supply, and to discuss the value of Federal subsidies in the solution of one of the most important of these problems, namely, financing the project. In the recent years of Federal subsidies considerable progress has been made by small towns and villages in the construction of water supplies. Many of these communities debated the water supply question year after year, and while they realized the advantages to be gained they dared not risk the financial obligations involved. It was frequently demonstrated conclusively that such projects could not be justified from a financial standpoint. With the advent of Federal subsidies in the form of P.W.A. and W.P.A. grants the picture changed. A project that could not be justified with the community bearing the entire cost became financially sound from the town's standpoint when supported by Federal funds.

As an example in this discussion I shall use the town of Lanesborough, Mass., which is situated just north of Pittsfield. A new water supply has just been completed in this town under Federal subsidies from both the P.W.A. and W.P.A. Lanesborough has a population close to 1250. Within the town are two villages, the Village of Lanesborough in the valley of the Housatonic River including a summer colony along the shores of Pontoosuc Lake, and Berkshire Village about 2 miles to the east in the valley of the Hoosac River. For more than 40 years the town of Lanesborough had considered periodically the advisability of providing itself with a public water supply. An engineering study and report were made for the town in 1896 and supplementary reports were made on several subsequent occasions. The State Department of Public Health had repeatedly warned the town against the continued use of private wells, many of which were

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subject to pollution. The townspeople realized the advantages to be gained from the construction of a public water supply, not only in the matter of public health but also for fire protection. They recognized that the lack of a public water supply had had an adverse effect on the growth of this suburb of the city of Pittsfield. Despite all the advantages to be gained by the construction of a water supply, it was evident from the engineering investigations that had been made in the past that such a project would be financially unsound, chiefly because the centers of population were widely separated, making necessary long pipe lines on which there would be relatively few consumers. That a public water supply has been finally constructed is due to two factors: first, and most important, is the financial assistance given by the Federal government; and second, the project was constructed by a fire and water district, formed for this specific purpose, rather than by the town as a whole.

An engineering investigation to determine the feasibility of a public water supply, assuming that some form of Federal aid could be obtained, was made early in 1938. The results of this investigation indicated the advisability of forming within the town two water districts, one including Lanesborough Village and the summer colony on the shores of Pontoosuc Lake, and the second, Berkshire Village. When the investigation was made there was no assurance that Federal funds could be obtained from the P.W.A., but it was reasonably certain that financial support would be given by the W.P.A. While there was insufficient labor within the town to permit the operation of a W.P.A. project, it was found that there was a surplus of labor in Pittsfield that could be used in this undertaking.

It was shown by the investigation that, with the assistance of such Federal funds, there could be installed in both villages, water supplies that would be self-supporting and would not involve excessive taxation or excessive water rates. The financial picture in the Lanesborough Village District was considerably more favorable than that for Berkshire Village. Ultimately, the Lanesborough Village District was organized and $75,000 was appropriated as the District's share of the cost of the proposed water suppy. This amount was raised by the issuance of 30-year serial notes bearing interest at the rate of 2¾ per cent.

This action was taken in the spring of 1938 when Congress had under consideration further P.W.A. appropriations. As there was no assurance then that additional P.W.A. funds would be available, the

District decided to construct its water distribution system as a W.P.A. project and to build its supply and storage works by private contract. An application for labor and certain materials was approved by the W.P.A., and work was started on the construction of water mains in September, 1938. In the meantime, Congress had appropriated additional P.W.A. funds. The District therefore decided to apply for a Federal grant for the construction of the supply works and storage tank. Such a grant was ultimately made by the P.W.A. and accepted by the District, amounting to 45% of the estimated cost of these works. Before the application was made, it was expected that the District would take water from the city of Pittsfield. This would have required a pumping station near Pittsfield, as the pressures in the Pittsfield system were not adequate to supply the needs of Lanesborough Village. It was also expected that a steel standpipe would be used for storage. With the prospect of obtaining a P.W.A. grant for the supply and storage works, the original plan was revised to make it possible for the District to construct its own supply works, using driven wells as the source, and to build a covered reinforced-concrete storage reservoir instead of the steel standpipe originally planned.

There has been excellent opportunity on this project to compare the advantages and any shortcomings of the P.W.A. and the W.P.A., respectively. From the standpoint of the engineer, construction under either of these agencies adds considerably to his troubles and to his engineering costs. In either case a third party representing the Federal Government has a financial interest, safeguarded by appropriate rules and regulations, which must be carefully observed by the engineer for the protection of his client.

Commenting first on the work included in the W.P.A. project, it should be said that we fully realized that construction under this agency involved many uncertainties. As matters turned out, most of our misgivings did not materialize, and, in general, the success of the W.P.A. project exceeded our fondest hopes. This was due in no small measure to the coöperative attitude demonstrated by the officials and engineers connected with the W.P.A. They recognized that this project was a desirable one which promised to produce something of real value to the community, and they went out of their way to assist the District wherever possible.

The engineers, including the office of the writer and Henry C. Neff, Civil Engineer of Adams, Mass., were given full charge of the

construction which was to be undertaken under the W.P.A. project. The writer's office employed a resident engineer and such inspectors as were necessary. The resident engineer served not only in the capacity of engineer but was virtually superintendent of construction. Fortunately, Ralph W. Armstrong who filled this position was eminently fitted for the variety of duties which it covered. The W.P.A. furnished a general supervisor who was responsible to the resident engineer. While there was some difficulty in securing a qualified supervisor, eligible for employment by the W.P.A., and replacements were necessary during the job, the general plan of organization worked reasonably well.

At the beginning of construction the District had no tools or equipment whatever. It was therefore necessary to arrange for the purchase or rental of construction equipment and tools as well as the materials that were to be used for the water distribution system. Contracts and specifications were prepared by the engineer for small tools and supplies, construction equipment and equipment rental, pipe, valves, hydrants, service pipe, brass goods, and all other materials required for the work. These materials were purchased by competitive bidding under six contracts, and with but one exception the contracts were awarded to the lowest bidders. Some ten thousand feet of cast-iron pipe were furnished by the W.P.A., this amount being determined by the number of man months of employment estimated to be given by the project.

A brief summary of the work done is as follows:

8-in., Class 150, C. I. pipe—unlined (tar-dipped)	15,800 ft.
6-in., Class 150, C. I. pipe—lined with bituminous enamel	15,200 ft.
2-in., Class 150, C. I. pipe	1,000 ft.
Hydrants, including 6-in. hydrant branch valves	38

Other items included the installation of copper tubing and fittings for house services, which work is still in progress, two submerged river crossings and an overhead river crossing suspended from a temporary wooden truss.

The cost of the work previously referred to is as follows:

	Federal Cost	
Labor	$97,000	
Materials	10,800	
Total Federal Cost		$107,800

District Cost

Materials	$32,500	
Equipment purchased	2,500	
Equipment rented	6,500	
Miscellaneous	900	
Total District Cost		42,400
Total construction cost, exclusive of engineering and supervision		$150,200

It will be seen that the total cost to the District amounted to $42,400 or about 28% of the combined expenditures for labor and materials, both Federal and District. Had this work been done by contract without Federal participation, it would have cost close to $100,000 and somewhat more if it had been undertaken as a P.W.A. project. On the basis of a 45% P.W.A. grant, the cost to the District would have been from $55,000 to $60,000. Either of these amounts are materially greater than the actual cost to the sponsor under the W.P.A.; namely, $42,400. From a broad economic standpoint, which considers Federal as well as sponsor costs, but discounting the factor of unemployment relief, the W.P.A. costs were of course much less favorable than would have resulted had the project been constructed under a P.W.A. grant.

At the outset, an accounting system was set up, and careful records of the cost of construction were kept throughout the period of construction, all records being subdivided to show the cost of labor, materials and equipment. These costs, covering a period of one year and including expenditures by both the W.P.A. and the Water District are condensed and summarized below. The cost of engineering and overhead expenses of the District office, as well as miscellaneous minor expenses associated therewith, are not included in these unit costs.

Earth excavation—average for entire period	$2.91 per cu. yd.
Earth excavation—omitting winter months, from December to March, inclusive	2.10 per cu. yd.
Earth excavation for four winter months only ...	5.08 per cu. yd.
Backfill	1.76 per cu. yd.
Rock excavation	9.44 per cu. yd.
Disposal of surplus materials	0.95 per cu. yd.

Hauling pipe	2.81 per ton
Furnishing and laying pipe, average for 6- and 8-in.	1.16 per. lin. ft.
House services to street line	$75.80 each or $1.80 per ft.
Hydrants	$117.00

It should be recognized that these prices include the cost of W.P.A. labor and that, with the exception of truck hire and rental of air compressors for excavating frozen ground during the winter months, labor saving devices were almost entirely absent. The cost of house services from the main to the street line involved the highest percentage of labor. Street crossings were made by hand-driving 1¼-in. steel pipe 5½ ft, below the pavement. Copper tubing was then inserted and the steel pipe withdrawn. This work was ideal for the winter months but was possibly somewhat extravagant in the use of labor.

On the Lanesborough project, as in many other W.P.A. projects, the supply of labor was greatest during the winter months when it could be used least effectively. This condition obviously operates to increase unit costs. The W.P.A. project at Lanesborough was set up to employ 160 men. During the best working conditions, the number of men seldom exceeded 125, whereas during the winter months the number rose to about 190. Since the primary function of the W.P.A. is unemployment relief, the sponsor can hardly expect to have labor furnished according to his needs. If overhead costs rise excessively during the winter months because the project is overmanned, the sponsor can do little but accept this condition.

Turning now to the P.W.A. project it should be said that the supply and storage works at Lanesborough were too small in size and cost to be well-adapted to construction under the somewhat intricate administrative machinery of the P.W.A. This was realized when the application for funds was being considered. It was recognized that a 45% Federal grant would not yield to the District an actual saving of 45%.

Under the P.W.A. project, two principal contracts were let: one for a 300,000 gal. covered reinforced-concrete storage reservoir including a control chamber and supply main; and another for connecting fifteen 2½-in. driven wells and constructing and equipping a pumping station. The equipment in the station included two 150-

g.p.m. electrically-driven centrifugal pumps, one with an auxiliary gas-engine drive, an automatic priming system, and the necessary control and metering equipment. Space and piping was provided for the future installation of a water softener. The cost of the storage tank amounted to $16,980[1] while the pumping station, including the necessary test wells, cost $12,260[2] giving a total cost of $29,240. While the final grant has not yet been received by the District it is expected that the total cost of these works to the District will not exceed $16,100. Had this work been done by contract without participation by the P.W.A. it seems reasonably certain that the contract prices would have been somewhat less. Unfortunately the letting of the two contracts came shortly after the flood and hurricane of September, 1938, when many local contractors were occupied with flood repair and restoration work. The effect of this latter condition probably more than outweighed any differences that might have occurred between bids taken by private contract and P.W.A. contract, respectively.

It will be remembered that in the early days of the P.W.A., projects estimated to cost less than $25,000 were not eligible for Federal grants. Whoever was responsible for setting this limit apparently realized that the administrative machinery of the P.W.A. was not designed for small projects. The requirements of the P.W.A. relative to the preparation of contract documents, the awarding of contracts, the inspection of materials, and the auditing and accounting procedures are substantially the same for a small contract of $25,000 as for one 10 times this amount. Small projects are generally constructed by small contracting organizations. In western Massachusetts, there is a considerable number of small contractors, but many of them have had little or no experience with P.W.A. work. They have heard much about the rigid requirements relative to the employment of labor; they have known of contractors whose payments have been held up because of delays in the payment of the final grant to the sponsor; and they are generally not willing to risk being placed in such a position themselves. The P.W.A. requirement that construction work be carried on during the winter months, while consistent with the chief objectives of this agency—to relieve unemployment—is especially

[1]Storage tank constructed by Frank T. Wescott, North Attleboro, Mass.
[2]Pumping station, General Contractor, Edward F. Hughes, Boston, Mass.
Pumping station, Equipment Sub-Contractor, Turbine Equipment Company of New England, Boston, Mass.
Pumping Station, Building Sub-Contractor, Jules Deloye, Lanesborough, Mass.

hard on a small project when the time for completion is generally short. Even though such a requirement be interpreted liberally, the contractor who ignores it when preparing his bid is taking considerable risk.

The experience with this small P.W.A. project at Lanesborough leads the writer to believe that the work could have been done at no greater cost to the District, had the latter furnished all materials and supervision, and used W.P.A. labor for the construction of the project. Prior to making a decision to apply for a P.W.A. grant, preliminary estimates indicated that the construction of the storage tank by W.P.A. day-labor project and the pumping station by private contract would cost about $3,500 more than under a P.W.A. project. In the light of subsequent experience with the two methods of Federal subsidy, it seems reasonable to conclude that both would have yielded about the same financial result to the District. It should be said that on a project twice this size the P.W.A. would have yielded the greater saving.

Considering the Lanesborough water project as a whole, it is obvious that the District derived a very substantial advantage by utilizing the subsidies offered by the W.P.A. and P.W.A. Had there been reasonable assurance that P.W.A. funds could have been obtained in the beginning for the entire works there is little question but what the whole project would have been done under that agency. However, the experience with the W.P.A. on the construction of the distribution system indicates that this Federal agency can be employed to greater advantage than is generally realized, especially if communities are willing to furnish ample funds for materials and adequate supervision.

At the present time, P.W.A. funds for new projects are not available and there is considerable question as to whether additional funds will be forthcoming in 1940. The W.P.A. has been recently reorganized, and it seems probable that it will be in existence for some time to come. New regulations of the W.P.A., effective January 1, 1940, will require sponsors to contribute not less than 25% of the cost of any project. This regulation should have a favorable rather than an unfavorable effect on water supply projects. There are few such projects that have been constructed in the past where the sponsor's costs have not exceeded 25% of the total cost. The 25% stipulation will have the effect of eliminating many undesirable types of projects, providing this requirement is rigidly enforced. Communities will have to in-

crease their appropriations as sponsors of W.P.A. projects, and more worthwhile projects should result. In the water works field, opportunities for the further development of desirable projects are by no means exhausted, even after eight years of work relief activities. Distribution-system extensions and reinforcements are still needed, and supply works in many towns are in need of enlargement and improvement.

In addition to improvements to existing public water supplies the possibilities for the construction of new supplies in many small towns and villages in New England should be explored in the light of available opportunities for Federal subsidies. According to a report published two years ago by the New England Regional Planning Board, there were in 1937 at least 115 towns in New England having no public water supplies where such supplies were considered necessary. The data accumulated by the Board were admittedly incomplete. Numerous important villages in the towns listed as having water supplies were not included in the report.

As in the case of Lanesborough, many of these places could not hope to have water supplies without financial assistance from some outside agency. While some of the communities could utilize the benefits offered by the W.P.A., others are not as favorably situated in the matter of labor supply. In Lanesborough, there were seldom more than 25 residents of the town who could be certified for W.P.A. employment. Had it not been for the surplus of labor in Pittsfield and adjoining towns, the W.P.A. water project would have been impracticable.

Under present conditions, isolated communities with a limited supply of eligible W.P.A. labor can do little in the way of providing themselves with public water supplies. The prospects of constructing supply works by private companies are certainly not inviting. If these communities are to realize the advantages of modern water works, some other form of subsidy than is now available must be provided. Federal subsidies, similar to those proposed for the construction of sewage disposal works by several bills considered by Congress during the past three years, may be the answer. The only sound justification for Federal subsidies for sewage disposal, other than for the relief of unemployment, is based upon the interstate aspect of the pollution of inland and coastal waters. From the standpoint of public health it seems to the writer that a village water supply has inter-

state aspects that in some cases may be far more important than those of stream pollution.

New England has been called the "Playground of the Nation". While other sections of the country may contest our exclusive right to this title, it is a fact that our largest single industry is that of supplying the recreational needs of thousands coming here from all parts of the country. These visitors as well as our own people travel through New England giving little thought to State lines. Many are simply touring and do not spend two successive nights in the same place. Small-town guest houses and tourist camps are gradually supplanting city hotels so far as the summer tourist is concerned. Increasing numbers of guest houses are being opened, and many of them are in towns having no public water supplies. For town or state health authorities to exercise adequate control of the individual water supplies in these places is next to impossible. Without such control, the opportunities for the spread of water-borne disease by this mobile summer population are exceedingly great. According to the survey of water-borne disease reported by Wolman and Gorman for the years 1920 to 1930,[3] nearly 20% of the cases of dysentery and typhoid fever in the United States were attributed to untreated groundwater supplies. Since 28% of the outbreaks of these diseases occurred in communities having less than 1,000 population it is probable that the groundwater supplies referred to were largely private wells, having inadequate sanitary supervision, rather than wells used for public water supplies.

A more recent report[4] by the American Public Health Association stated that over 50% of the outbreaks, in the United States and Canada, were in communities of under 1,000 in population. It is also stated that 39% of the typhoid fever cases occurred in the same group of communities in the United States and 63.5% in Canada. The investigation further reveals that by far the largest number of outbreaks and cases of typhoid fever were attributed to the use of untreated groundwater.

Comparison of the later report with that of Wolman and Gorman indicates that since 1930 the trend has been for the percentage of outbreaks and cases of typhoid fever, occurring in communities under

[3]The significance of Water-Borne Typhoid Fever Outbreaks, 1920-1930, by Abel Wolman and Arthur E. Gorman, Journ. A.W.W.A. February, 1931.

[4]Water-Borne Outbreaks in the United States and Canada 1930-1936. Report of the Committee on Water Supply. Annual Year Book of the American Public Health Association, Vol. 20, No. 2.

1,000 in population, to increase over the earlier period. This is probably due to improved supplies and more adequate control over water purification in the larger towns and cities, while conditions remain substantially unchanged in the small communities.

Considering all of these factors, the small town or village water supply problem has indeed an interstate aspect that may, under certain conditions, be far more important than sewage pollution in interstate rivers and coastal waters. At least one of the Federal pollution bills previously referred to would provide subsidies in the form of 30% grants for the construction of municipal sewage disposal works. We have our Rural Electrification Administration; why not a Rural Water Supply Board with authority and funds to give financial aid to small towns for establishing adequate water supplies? Some will say that the "alphabet soup" is already too thick. The writer's answer is that the addition of water to soup—but should I say more! Whatever form the subsidy takes, the principle of providing outside financial aid to small isolated towns and villages for public water supplies appears to be reasonably sound. If we are satisfied that such supplies are essential to the perfection of a well-rounded national health program, then some means should be found to supply the needed subsidy.

In closing may I say a word of appreciation for the assistance given in the preparation of this paper by Herman G. Dresser who served as assistant engineer on the design of the Lanesborough water supply.

SOME PROBLEMS OF WINTER OPERATION

BY ALLAN K. GRIMMER*

[*Read September 15, 1939.*]

In Canada winter conditions affect every branch of waterworks, and the farther north the plant is located the more important do these considerations become. The following notes are based on results of experiences in the town of Temiskaming, Quebec, where the thermometer at times drops to sixty odd degrees below zero, and this introduces problems that do not prevail in more southerly Canadian plants.

The pumping station building and its equipment are fairly easily taken care of by hot water or steam heat, but we have on occasion found it necessary to install electrical heating on the supply lines to the chlorinator to keep it in proper working order. The principal difficulties occur outside on mains, services and hydrants, and these notes will particularly refer to this phase of the problem.

The mains and services in Temiskaming are located in soil comprising glacial drift which is from 40 to 60% boulders. There is also considerable solid rock. All mains are laid with a minimum cover of 5 ft., as also are the services. This appears to be adequate cover for both, as little difficulty has been experienced with the permanent installations where this cover has been provided. The mains are of cast iron and the services of 1-in. galvanized pipe, which has been used for all domestic services; and it may be of interest in passing to say that, although these galvanized-iron services have been installed now for twenty one years, there has not yet been a single renewal made. It has been further observed in isolated cases, where these services have not been put down to the full coverage of 5 ft., that if they are situated in a sodded lawn, the frost hardly ever goes into the ground over 3½ ft., whereas in travelled streets frost has been observed to a depth of 4½ ft. Most of the freeze-ups to services have occurred on those which are connected to houses without cellars or heat in the basements.

These freeze-ups are taken care of by a portable thawing outfit consisting of two 15-k.v.a., 2200-volt, 110/220 standard transformers so connected as to reduce the voltage to 50 to 55 volts on the secondary

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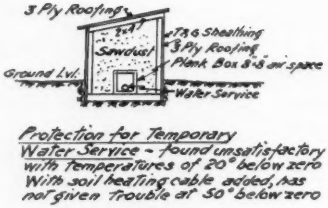
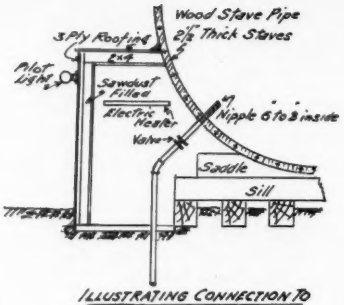
side. This outfit thaws out the ordinary services in a very few minutes, while in the cases of hydrants it requires an hour or more to do so. The secondary side of the transformer is connected to the nearest available outside exposed pipe or hydrant and the other connection to a stop cock or pipe in the basement. It has, however, been noted that once a service freezes up during the winter it is very likely to repeat, so that an effort is made to arrange with the occupant of the premises to let the water run continuously after the first freeze-up.

Owing to local conditions, there are quite a number of what may be termed temporary water services, and these are our biggest service problem. Their installation is made in several ways: first by enclosing in partially insulated boxes. In this instance the service pipe is placed in a wooden box 8 in. square which rests on mud sills. This, then, is enclosed in a second box with removable roof approximately 30 in. wide, and the space between the box is filled with sawdust. If there is quite a snow cover, this is usually effective, but in extremely severe winters, or winters with low snowfall, this is not satisfactory, and electrical heating has now been added to this arrangement. This is provided by using soil-heating cable which is available in 60-ft. lengths for 115-volt current, and the cable usually heats itself to 175° F. Where one length of cable is insufficient, two or more lengths have been spliced together. This, of course, reduces the temperature in the cable, but has been adequate to prevent freezing whenever used. In special instances, we have used 220 volts on this cable, but for safety and to prevent burn-outs we prefer 110 volts whenever possible. The connection between the cables and with the supply must be taken above the ground or box and be made with condulets. The diagram accompanying this paper shows the general method of connection. Each 60-ft length of cable uses approximately 3 amperes at 110 volts and a 120-ft. length of cable will therefore use 1½ amperes for each 60-ft. length. Similarly the amperage is reduced as other lengths are added. The longest installation that has been made locally is that in which four lengths of soil-heating cable were used connecting an approximate over-all distance of 230 ft.

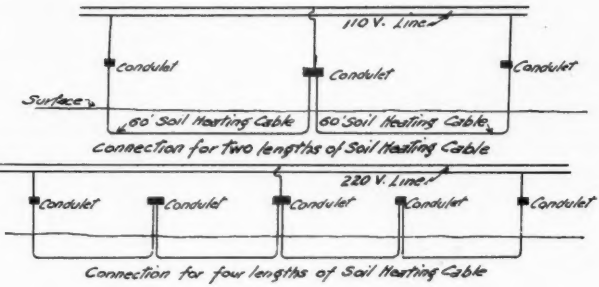
The second temporary water-service condition with which we have to contend is that in which it is not possible to get the service more than a few inches under ground due to the fact that solid rock would be encountered. In these cases we place a soil-heating cable in a conduit and lay the same parallel and close to the service itself. Although there are instances where these services are only 10 or 12 in.

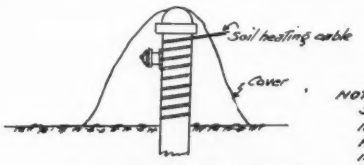


Protection for Temporary Water Service - found unsatisfactory with temperatures of 20° below zero With soil heating cable added, has not given trouble at 50° below zero



ILLUSTRATING CONNECTION TO WOOD STAVE PIPE





NOTE: Soil Heating Cable 18 gauge Nicrome resistance wire insulated in lead sheath.

ILLUSTRATING METHOD OF THAWING HYDRANTS WITH SOIL HEATING CABLE

under travelled streets, there has never been a freeze-up since the cables were installed. The cost of operation of this method is relatively cheap in Temiskaming, as current costs slightly less than ½¢ per k.w.hr. On this basis, a 60-ft. length of cable in constant use runs up a bill of about $1.10 per month. The supply for most of these temporary services is taken from a 13-ft. pipeline which passes through the town, and which is the source of power for the pulp and paper industry located there.

Experience has shown that this pipeline becomes coated on the inside with a ring of ice. As a result it has been necessary to extend the service nipple into the pipeline at least ten inches to prevent freeze-ups at this point. These connections ar housed in and prevented from freezing up by strip heaters of 1000-watt capacity. A light in series is connected with the strip heater and by this means their operation is observed.

The wood-stave pipelines create a further problem in town operation. Being exposed on the surface, they are subject to contraction and expansion. This causes considerable leakage at times, and, until the soil-heating cable was used to maintain open passages for the discharge of leakage, the leakage built up ice on the streets in places to a depth of four feet. Now the local power company installs lengths of this cable so that open channels are maintained to catch basins from which leakage is discharged, and the ice nuisance is thus avoided. The cables for this purpose are also laid in conduit and throughout the winter will maintain an open channel in the ice approximately 18 in. in diameter. The intake to the pumping station is also taken off the same wood-stave pipeline. It is 12 in. in diameter and is connected to the pipeline by a flanged saddle. Controlling gates are located in a more permanent house on the side of the pipe, which is heated by electricity. In this instance, it has not been found necessary to insert a nipple into the pipeline. Apparently the flow of water into the pumping station is sufficient to keep this open.

One of the most serious problems that we have encountered is maintenance of hydrants in good working condition. Owing to local conditions, underground water or leakage from mains at times enters the hydrants from the drip in the base, rises in the barrel and freezes. Consequently these drips are now connected directly to the sewer so that the hydrant can drain itself and also prevent the ground water from rising in the barrel. It is the writer's opinion that for winter conditions the sliding-gate type of hydrant is better than the type in which the spindle in opening the hydrant moves the gate horizontally. Daily inspection is maintained on all hydrants during the winter to see that they are in working order. When frozen, we again use soil-heating cable and in this case wrap the entire 60-ft. length about the exposed part of the hydrant above ground. The heat thus generated apparently travels down through the hydrant barrel and the spindle thus thawing the ice which, when started, is removed by opening the hydrant and discharging it through the outlet. During this process,

the hydrant is covered either by canvas or other protective means to retain the heat about it. We have experimented with salt and alcohol for thawing hydrants, but this has not been satisfactory.

There have been occasional freeze-ups in mains, and a word of caution here may not be out of order. The joints of the mains may be completely watertight but not completely electrically tight. As a result the current will create an arc whose temperature melts the lead and causes leakage. Consequently, care must be exercised in thawing operations which we usually attempt with 50 volts and 600 to 800 amperes.

As a result of experience in Temiskaming, it would appear that there is no objection to galvanized-iron pipe as water service when laid to a depth that will protect it from freezing, as it appears to have a life of over twenty years. It is also obvious that all hydrant drips should be connected directly to the sewer, that electrical thawing transformers are the quickest and cheapest means of thawing freeze-ups, and that soil-heating cable has innumerable uses and applications for maintaining service on temporary lines or for maintaining open channels through which leakage can be discharged into the sewer system.

Although the operation of the over-ground pipelines for power purposes and mill supply do not come directly under the writer's control, it has been observed that there are no serious problems in maintaining them in operation even at the low temperatures experienced. When they were installed there was some question as to whether ice formed on the inside of the pipes would cause some damage to the generators, but this appears to melt gradually in the spring and so far has not caused any trouble or inconvenience.

RIVER CROSSINGS

BY CARDEN T. HEENEY*

[*Read September 15, 1939.*]

The carrying of a water main across a river or a canal is one of the many problems with which water works engineers and superintendents have to contend. The method of crossing the river or canal is something that must be determined according to local conditions, There are many variables to be taken into consideration, such as depth of stream, velocity of stream, conditions encountered at the river bed, size of main, and climate, but in general a main is carried across a stream as either one of two types of crossings: (1) submerged crossings and (2) overhead crossings. Although in some cases, as in the Greater Winnipeg Water District, tunnelling has been used.

This paper will discuss river crossings at Ottawa, and in particular an overhead crossing that was completed in 1937.

Submerged Crossings. At various places in the distribution system of the city of Ottawa, it was necessary to carry mains across the Rideau Canal and the Rideau River. In these cases, submerged crossings were used. There are ten water mains crossing the Rideau Canal and five crossing the Rideau River, the mains varying in diameter from 6 to 30 in. In all cases, cofferdamming was used. The water mains crossing the Rideau canal were laid during the winter months, for at that season the water level in the canal is lowered to within a few feet of the bottom, and cofferdams could be built without a great deal of difficulty. Trenches were excavated for the canal crossings and, due to the unstable nature of the soil at the river bottom, it was necessary to construct a concrete mat to carry the larger sized pipes, the concrete mat being supported on wood piles. Bell and spigot cast-iron pipe was used and jointed with hemp and lead. Mains crossing the Rideau River were, in most cases, laid in the autumn months, for at that time of the year, the river is quite shallow, and again cofferdams could be constructed without a great deal of difficulty. It was not always possible to lay the main in a trench, so, where necessary, concrete was placed on the upstream side of the

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pipe to protect it. A pressure of approximately 65 lb. per sq. in. is carried in these mains.

Overhead Crossings. The Ottawa Water Purification Plant and Main Pumping Station are situated on Lemieux Island, in the center of the Ottawa River, one-half mile upstream from the Chaudiere Falls. In as much as the water purification plant is situated on an island in the center of the river, it is necessary to transmit the filtered water from the island to the mainland, over a bridge structure. Prior to 1937, the city had been entirely dependent on receiving its water supply by means of dual pipe lines, suspended on a concrete arch bridge, which was constructed in 1918. For some time it had been felt that the security afforded by the dual pipe lines was not sufficient in itself and at all times constituted a potential hazard, in as much as a failure of the original structure might result in a simultaneous fracture of the dual pipe lines.

It was, therefore, with a view to avoiding the foregoing possibility of an interruption of the water supply and to provide additional security that, during the latter part of 1936 and the early part of

48″ Steel Cylinder Concrete Pipe on Steel Pipe Carrying Structure
Lemieux Island to Mainland, Ottawa. Ont.

1937, a 48-in. diameter water main of steel-cylinder concrete pipe was installed from the filtered-water reservoir of the Ottawa Water Purification Plant on Lemieux Island, to a point on the mainland, some 2200 ft. away, where it joins with one of the dual pipe lines carried across the river on the concrete bridge.

The new pipe line is carried across the south channel of the Ottawa River upon an entirely separate structure, a steel pipe-carrying structure, approximately 100 ft. downstream from the concrete arch bridge upon which are suspended the dual pipe lines mentioned before.

The steel-cylinder concrete pipe line and the steel pipe line it connects with are used as low-pressure pipe lines. The hydraulic gradient of these lines is such that water from the filtered-water reservoir can flow through them to the suction side of the Queen Street West Pumping Station, which contains turbine-driven pumps, and the water is pumped from there to the distribution system. The second steel pipe line on the concrete arch bridge is used as a high-pressure pipe line, from the Lemieux Island Pumping Station direct to the distribution system.

A steel truss structure supported on piers was used to carry the 48-in. steel-cylinder concrete pipe across the river, and provision was made on it for a second pipe line, to be laid at a future date. The pipe-carrying structure supports a length of 619 ft. of pipe. The abutments for the pipe-carrying structure are of reinforced concrete construction with a bench to receive the trusses, and the back and wing walls rise to an elevation approximately five feet above the pipe-line to serve as retaining walls for the protective covering of earth filling to be placed over the pipe line approaching the abutments.

Seven piers are used to support the structure, two of which are on a small island, known as Belle Island, and these two are of reinforced concrete construction; the other five piers are in the water. In order to avoid cofferdam work for the five piers in the water, an unusual type of pier construction was used. The piers are steel bents surrounded by skin plates, to form a shell, the joints in the skin plates being made water tight, and to the bottom of the legs of the bents are welded base plates, four to each shell. The whole was erected on shore and floated into position between two large pontoons, and lowered onto and bolted to anchor plates set at the river bottom. The shell when placed, was sealed around the bottom on the outside, and pumped dry; then rock bolts were placed in the river bottom and the shell filled with concrete to give the finished pier.

To carry out this type of pier construction, an accurate survey of the river bottom was first required, and this was done with divers. From the survey, the details of the piers were made. The setting of the anchor plates and anchor plate bolts at the river bottom, to receive the pier bents and shells, required accuracy, and this work was carried out by the engineering staff of the water department. Accurately to locate the points on the river bottom for the anchor bolt holes, a rectangular angle-iron frame work, or template, was constructed, the template being made in three sections, to facilitate handling; and a combination of one, two, or three sections was used, so that when placed there would be at least one foot of the top section projecting above water level for the purpose of lining it in.

It might be mentioned that the position of the anchor plates for any one pier was not necessarily symmetrical about the center-lines of the pier, nor was the elevation of the four plates for any one pier necessarily the same. Due to the contour of the river bed there are variations as high as 3 ft. 6 in. between the elevations of the four plates for one pier; also as the legs of the bents are sloped, the distance to the center of the anchor plates, from the center-line of the pier vary according to the elevation of the plates. The template was designed and constructed so that it could be used for all five piers and take care of all these variations. The template was supported on four 2-in. pipe legs, so arranged that the template could be made level at all times.

When the template was accurately set, four steel bars were slipped through pairs of adjustable slots, the slots being adjusted to make the center of the bars, the center of the anchor-plates for the pier. To the bottom of the bars were fastened plates drilled to correspond with the anchor-plate holes, and the divers used the holes in the plates for the center and guide to drill the anchor-plate bolt holes. Sixteen holes were drilled for each pier, four for each anchor plate, and when the drilling operations were completed, the template was removed and the anchor bolts grouted in.

For the grouting in of the anchor bolts, an ordinary plastic caulking gun, with a 4-ft. tip was used. The gun was filled with grout at the surface and lowered down to the diver, who ran the tip to the bottom of the hole and forced the grout into place. In mixing the grout for this purpose it was necessary to have the grout of one definite consistency, at all times, otherwise it would not work in the caulking gun. When the grout had been placed, the bolt, with split

end and wedge, was driven into place, leaving the 18 in. of threaded bolt above the rock surface. The anchor plates were immediately placed over the bolts and left until the grout set. The next day, using an extended levelling rod, specially weighted, the anchor plates were brought to the correct elevation by adjusting the supporting nuts on the anchor bolts. The diver used a small machinist's spirit level, to ensure the plates being level. The bolt holes in the anchor plates were slotted 8 in. in one direction and the bolt holes in the base plates of the bents were slotted 8 in. in a direction at right angles. In placing the pier bents and shells, slight discrepancies in alignment were taken care of, by shifting through the slotted holes.

With the anchor plates set, erection of the pier bents and shells on shore, took place. The pier bents were delivered to the site, with the nose plates in position; the bracing and side plates to be erected on the site. In erecting the shell on shore, the bents with nose plates were set up in proper relationship to one another and the bracing bolted in, after which the side plates were bolted on, leaving only four vertical seams in the shell. The bottoms of the side plates and the nose plates were cut, in the shop, to fit within 4 to 6 in. the contour of the river bottom. The bolts for the side plates were spaced at 3-in. centers and below water line. Lead washers were used to prevent any leakage through the bolt holes. To make the shell completely water-tight, the four vertical seams were welded from the bottom to a point approximately 1 ft. above water level.

To move the shell from shore and place it on its anchor plates, it was swung out by derrick and suspended on "A" frames, between two pontoons and floated from shore to its position. The locating and placing of the shells was somewhat simplified by the close proximity of the new structure to the reinforced concrete arch bridge, not only because it allowed the use of two transits, at right angles to one another, to line the shell in, but, also because of the fact that the new structure was downstream from the old one it was possible to place winches on the old structure to maneuver the pontoons, with the shell suspended between them, up or downstream, as required. Movement across the river was also guided by winches, the winches being placed on the mainland and the island. By the use of the winches it was possible to bring the shell directly above its anchor plates. Lowering of the shell onto its anchor plates was guided by chain-blocks from the "A" frames, the position of the shell being constantly checked as it was lowered to within 2 or 3 in. of the

anchor plates. The divers then guided the base plate bolts into the anchor plates as the shell was allowed to settle the last few inches. Any slight discrepancy in alignment was now corrected by using the slotted holes in the base plates or anchor plates, before the bolts were tightened.

To seal the shell and permit the pumping of it dry, the 4- to 6-in. opening between the shell and the river bottom was first tightly jointed or packed with sand bags, using about a 1:6 dry mix in the bags. With the opening packed in this way a steel form was then erected around the outside of the shell, 3 ft. away and rising 30 in. above the rock level and a depth of 24 in. of 3000-lb. concrete was placed between the shell and the form. The concrete for this purpose was lowered to the river bottom in a large bucket with a sliding bottom, the divers guiding the bucket at the bottom and placing it either on the bottom before opening the sliding door or else allowing it to come in contact with previously placed concrete, before emptying. The sealing concrete was allowed to set at least 48 hours before the shell was pumped dry. This method of sealing the bottom of the pier shells was found to be quite successful in all five cases, and no shell required more than 60 minutes to be pumped dry after sealing.

With the pier shell dry, fifty 4-ft. holes were drilled in the rock bottom, and 1-in. diameter rock bolts 8 ft. long were grouted in. All rock bolts had split ends and wedges, and the grout was placed in the hole, using the caulking gun, before the rock bolts were driven into place. With the rock bolts in place the shell was filled with 3000-lb. concrete. In placing the pier shell concrete, the pontoons were used to good advantage. By placing the pontoons end to end and erecting a trackway upon them along which a dump-body conveyor, powered by a gasoline hoist, could run, it was possible to mix the concrete on shore, or on the reinforced concrete arch bridge, and haul it to the pier for placing.

Two pontoons that were used for placing the pier shells, etc. were primarily built for the purpose of placing the trusses. The two trusses for a span were set up on shore and the bracing placed and rivetted. When ready, the span was placed on the pontoons, the pontoons being at about the quarter points of the span length, and supported with blocking and jacks at an elevation that would allow the bottom chord of the trusses to clear the top of the pier or abutment. Using winches, the pontoons carrying the trusses, were floated out into position and by use of jacks were lowered onto the piers or abutments. The

trusses, when placed, were lined in, and then the bolt holes drilled for the bearing plates. Cross beams, gantry rails, cradles for the pipe, and handrails were placed on the structure, after it was set. A gantry with a 10-ton block was placed on the structure, the gantry being of such dimensions as to span two pipe lines and with sufficient head clearance as to allow a length of pipe to be picked up by it, and to be carried along, over the top of the pipe lines.

The 48-in. steel-cylinder concrete pipe consisted of a 3/16-in. electrically welded steel cylinder lined with 1¼ in. and covered with 2 in. of reinforced concrete, made up in 16-ft. lengths, except when a shorter length was required to ensure the joint falling clear of a supporting cradle. All pipe-joints of the crossing, except six, were of the bell and spigot type, hemp and lead being used for jointing material, and then surrounded with a reinforcd concrete collar. The other six joints were Dresser couplings used as expansion joints placed to fall at the same point as the movable bearing plates of the trusses.

Insulation. The 619 ft. of steel-cylinder concrete pipe that were laid on the pipe-carrying structure are exposed to very extreme weather conditions, and it was necessary to insulate the pipe. Before any insulation was placed around the pipe, 1¼-in. steam pipes were placed on either side of the 48-in. pipe, the steam pipes being placed by civic forces. The insulation contractor then covered the steam pipes with a half-section of 4-ply pre-shrunk asbestocel insulation 1 in. thick, the portion of the steam pipe next to the large pipe being left open and the half insulation being securely wired so that it would hold its position. A layer of high-rib expanded metal was then wrapped around the 48-in. pipe with the steam pipe inside the layer, the high-rib expanded metal being of sufficient strength and rigidity as to securely hold the insulation proper in place and keep it away from the barrel of the 48-in. pipe. In this way an air space was created next to the pipe, and the steam line is within this air space. Two separate layers of best quality rock cork were then applied, all joints of the rock cork being tightly butted, and the joints of the second or outer layer being so arranged that they did not coincide with those of the first or inner layer, either horizontally or transversely. The rock cork was held in position with ½-in. wide Signode strapping spaced 12 in. apart. Over the rock cork was placed a ½-in. wire mesh to which was applied a coat of asbestos-cement felting with a minimum thickness of ¼ in. and over this was placed a coat of plas-

tic asbestos-asphalt weatherproofing compound with a minimum thickness of ¼ in. and so compounded as to withstand the action of the weather and to resist drying and cracking. This coat was finished with a trowel to leave a smooth surface.

The insulation contractor had to guarantee the following:

(1) The elasticity of the weatherproofing coating.
(2) That the insulation was sufficient to prevent still water in the pipe from freezing during a 6-hour period under minimum weather conditions, at an atmospheric temperature of 30° F. below zero.
(3) That no ice formation will take place on the interior walls of the 48-in. steel-cylinder concrete pipe during any period in the winter season when a minimum flow of 4 m.g.d. is maintained.

All guarantees made by the insulation contractor were independent of the use of the steam line that was inserted in the air space. The steam line, which is connected to a low-pressure steam boiler and vacuum return pump, was placed by city forces and is an added protection to the city.

Thermometers were inserted into the air space which surrounds the pipe, and during the past two winters, temperature readings have been taken twice daily. At no time has the temperature of the air-space dropped lower than 26° F., although air temperatures have dropped below zero for five and six days in succession, the minimum temperature being 26° F. below zero.

As mentioned previously, the pipe line is used as a low-pressure main, the pressure being approximately 8 lb. per sq. in. During the winter months, a minimum velocity of 0.6 ft. per sec. is maintained with an average daily velocity of approximately 1.0 ft. per sec.

PROTECTION OF STANDPIPES EXPOSED TO EXTREME LOW TEMPERATURES

BY H. G. HUNTER*

[*Read September 15, 1939.*]

There are very few standpipes, that is tanks resting on foundations that are brought to the ground level, in Canada at the present time, and those that are known to the writer are in the immediate vicinity of Montreal and are probably 20 to 25 years old. They all appear to be about 20 ft. in diameter and of varying height, probably the highest of them 80 ft. They are not covered by a roof, and apparently the low temperatures during our winters have not affected them to any great extent.

The standpipe at St. Laurent, which is a suburb of Montreal, was in service for a great many years, and the only trouble ever registered for cold temperatures was the loss in capacity, that is, the water would freeze to the sides of the tank and ice would form in the top of the tank. It is said that the loss in capacity due to this freezing cut the storage down as much as 30 to 40%.

The standpipe in the town where I live is 20 ft. in diameter and 80 ft. high. It is over 25 years old. As I have had more or less to do with the waterworks, I know that there has been very little trouble from freezing. I have no doubt that the most useful capacity of this tank is probably at times reduced 20% by the freezing that takes place. There is also a standpipe at Pointe Claire, a few miles west of Montreal, which has been in use for a long time and apparently has never given any serious trouble from freezing. We know that large amounts of ice form in the top section of these tanks, in fact this ice has been seen rising above the top of the tank in the spring of the year or when the weather begins to get warm and the sun is stronger. Apparently the sun melts the ice at the sides of the tank, finally sufficiently so that it lets go and floats. If the water is high enough in the tank the ice will appear above the top of the tank.

In the western part of Canada there are still a few standpipes. I am advised that there is one at Portage Laprairie, two at Saskatoon, one in Lethbridge, one in High River, and one at Bassano. Mr. John

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Haddon, of Haddon and Miles, Consulting Engineers, Calgary, has kindly furnished this information and he says that with temperatures as low as 50° F. below zero ice will form anywhere up to a foot thick and that in the spring it usually detaches itself and floats; also that these standpipes are in no way damaged by this freezing.

Temperatures in Montreal are not often colder than 20° F. below zero and then for only a few days, yet it has been known to be 40° F. below zero (F.). This temperature is very exceptional. At Winnipeg, records show that last winter there were 155 days when there was frost.

When I was with Mr. M. M. Tidd, Consulting Engineer, Boston, Mass., a good many years ago, I was rodman on the Randolph waterworks and this system had two standpipes with tops as I remember it about the same level. One standpipe was in Randolph and the other in Holbrook. For two or three years, there was trouble in the winter with the main pipe breaking just where it joined the bottom plates of these standpipes. I was sent to Randolph to observe for my employer what was going on from freezing in very cold whether. This required that I make observations looking into the top of the standpipe. The standpipe at Randolph I believe was 35 ft. in diameter and 125 ft. high. I well remember how the inside of these tanks looked. Down about 20 ft. there was on the sides of the tank ice about 1 ft. thick, thickest at the top and in the middle. Also there were floating and moving balls of ice from 6 in. in diameter to perhaps 2 ft. or 3 ft. These balls of ice were kept in motion by the rising and falling of the water in the tank, and when the water was falling they would sometimes bridge and hold until the water was lowered away from them; then they would let go and drop with a splash. The same was true when the water was coming up and they would hold until they were submerged and then let go and bob up. The moving and wetting and freezing of these balls increased their size so that they would crowd and bridge and at times hold up until there was quite a shock when they did drop. This was not, however, the cause of the breaking of the main pipe connection.

Standpipes must be tight. Very small leaks in seams or around rivets may cause a lot of trouble in cold weather. The water from a leak will freeze, and a leak of about 1 1/3 pints per minute will hang about one ton of ice on the side of the standpipe in one day. When I started in the waterworks business in Mr. Tidd's office, standpipes were in vogue, but today, in this vicinity anyway one never hears of a standpipe being built. Elevated tanks have taken the place of standpipes.

I think that one of the first elevated tanks came out of Mr. Tidd's office. It was designed by Freeman C. Coffin and was built at Fairhaven, Mass. It is quite probable that if the old standpipes had been roofed over they would not have had so much ice form in them. I feel sure that there is very little ice on the sides from the bottom up to near the top and that if the top were protected it would help a great deal. I have noticed a description of a standpipe recently built at Scituate, Mass. This tank is 55 ft. in diameter. This appears to be a welded job and the top is apparently covered in.

The spheroidal tanks now being designed and resting on foundations at ground level are structures never dreamed of until recent years. The tank recently built at Brookline, Mass., having a diameter of 94 ft. and a height of 47 ft. holds 1 2/3 m.g. of water. The writer is doubtful if past experience with standpipes will be of much use in coming to any conclusion as to the effect of freezing in tanks of this shape. Older members will remember the bottle-shaped standpipe at Providence, R. I. that failed on account of freezing.

In 1920, the late Mr. H. P. Eddy, of Metcalf & Eddy, Consulting Engineers, Boston, having to make a decision respecting a standpipe that he was about to construct, obtained a great deal of information in regard to cold-weather conditions for standpipes in the Northern United States and in Southern Canada. I feel quite sure that this paper has been useful to engineers and superintendents for a number of years and it is recommended for the consideration of parties desiring to obtain information on the protection of standpipes exposed to extreme low temperatures. This paper may be found in the Journal of the A. W. W. A. Vol. 7, 1920, p. 579. Briefly there are 127 standpipes listed, 63 of these are on surface water supplies. Apparently there was no difficulty with these tanks from freezing. However, sound advice is given by Mr. Eddy in his conclusions based upon the records as submitted to him.

BROOKLINE'S SPHEROIDAL TANK

BY WALTER B. BUSHWAY*

[*Read November 16, 1939.*]

General. The Water Department of the town of Brookline has recently placed into use for its high-service system a spheroidal water tank. The tank is located on the highest elevation in the town, Single Tree Hill, where the normal ground elevation is 334 ft. above mean high water in Boston Harbor. Adjacent to Boston, Brookline has a population of 53,000 with an average consumption of 5 m.g.d., although during the hot days of last July the demand reached over 12 m.g.d.

Our distribution system is divided into a high service and a low service, both with pressure ranges of from 35 to 110 lb. per sq. in. Due to the character of the properties served, the high-service system takes approximately two-fifths of the total consumption under normal conditions, and one-half during heavy draughts.

Storage accommodations on Single Tree Hill consist of a 4½-m.g. covered reservoir and the new spheroid with a capacity of 1,660,000 gal. The floor elevation of the older reservoir is 323.2 ft. with a head range of 22 ft. while the new tank has a floor elevation of 328 ft. and a head range of 46 ft. By a system of piping and check valves, the buildings on this hill are supplied at all times by tank pressure, even though the high-service system may be fed by the reservoir. Water for our high service is pumped directly by the high-service-station into the distribution mains, the surplus being delivered to the tank or reservoir, depending on which one is in service.

We have never been bothered with ice formation, due to the fact that the temperature of the water delivered to the tank seldom falls below 42° F., and that our daily pumping time averages 12 hours in winter.

Old Tank. The new tank replaces a wrought-iron tank of 440,000-gal. capacity, 50 ft. in diameter and 30 ft. in height, covered by a wooden roof. This tank was erected over 55 years ago and has been in continuous service. It was constructed with double-riveted, lapped, horizontal joints and single-riveted, lapped, vertical joints. Some

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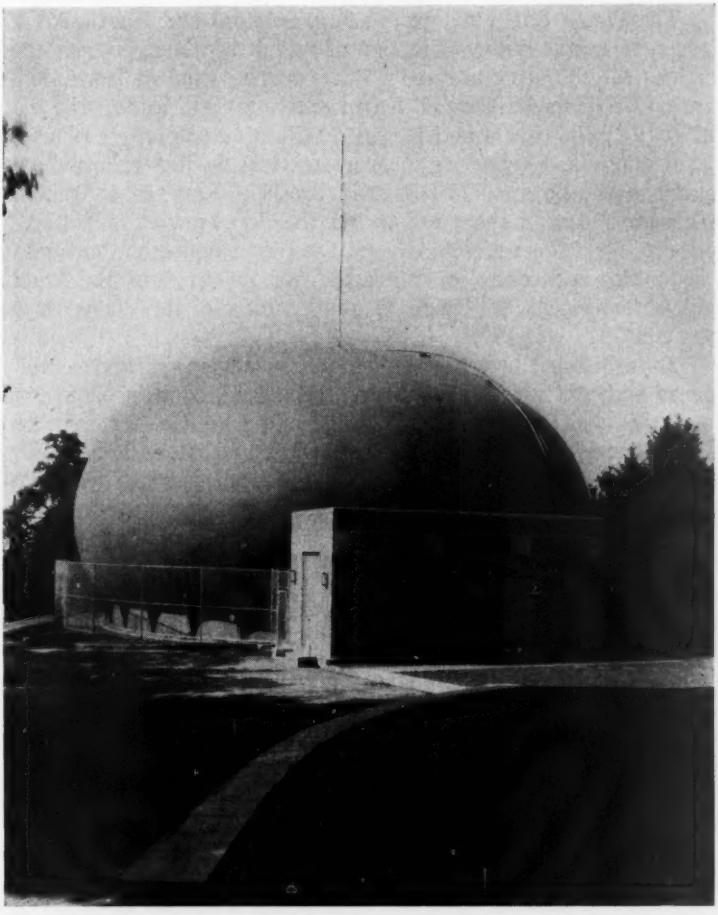
years ago it had become much too small and had developed signs of leaking.

Preliminary Studies. After over a year of preliminary studies and investigations, involving not only capacity and construction requirements but the pacification of location objectors as well, the Superintendent was authorized to prepare tentative data and speci-



SPHEROIDAL TANK, BROOKLINE, MASS.

fications for the erection of a tank and necessary appurtenances. The tank was to have a capacity of one million gallons within a head range of 24 ft., with the elevation of the top of the structure not to exceed 375 ft. which is the limit imposed by deed restrictions. The tank was to be of copper-bearing steel and electrically welded.

On the basis of preliminary calculations, an appropriation of $95,000 was asked for and granted at the annual Town Meeting.

The Water Board designated Fay, Spofford and Thorndike, Engineers, to handle the investigation of submitted plans, prepare specifications for the structure and welders and to conduct inspection of erection; William R. Conard, Engineer, to test and inspect the material at the mill. Little and Russell, Architects, to prepare plans and specifications and supervise the construction of ring wall, slab, tunnel and gauge house; and Olmstead Brothers, Landscape Architects, to design and plan the grading and the development of a pleasing and effective foliage screen. All of the field engineering and general coördinating and control of contractors was delegated by the Superintendent to Kenneth W. Robie, Works Engineer of the Water Department staff.

Bids. Sealed proposals called for by advertising were publicly opened and read with the result that the following lowest bidders were given the work: The Chicago Bridge and Iron Co. for a spheroid tank; Grande & Volpe for concrete work and gauge house; White and Franke for tree hauling and planting, and trees and shrubs that had been selected during the previous year were furnished "en habitat" by the Eastern Nurseries. All pipe work was done by men of the department, while grading, loaming, retaining walls, and asphalt driveways were handled by the F. L. Love Contracting Co.

Foundations, Tunnel and Gauge House. The tank rests on a reinforced concrete ring-wall and floor slab, the former 20 in. in width and the latter 6 in. thick. The ring wall rests on a reinforced concrete footing 20 in. thick and 7 ft. in width and bearing on virgin ground, thus creating a unit earth loading of 2.4 tons per sq. ft. Preconstruction tests disclosed all of the sub-soil to be hard-pan. Before placing the floor slab of the tank, all trenches were back-filled with compacted sand and gravel and the sub-grade was adjusted with compacted crushed stone. Pre-mixed concrete was used throughout with a 4-in. slump for water content.

Slab Drainage. The floor slab was laid in quarter segments, each segment draining toward its radial center which in turn drains to a

catch basin outside and attached to the ring-wall. The purpose of this construction is to carry off condensation and at the same time to isolate and determine any bottom leakage at some future time.

Slab Cushion. On the slab are laid 18 in. of 1-in. crushed stone, compacted in layers of 6 in. by a caterpillar tractor and finally a 6-in. sand cushion, compacted to the grade of the bottom of the floor plates of the tank.

Ring Wall. The ring wall acts as a support for the vertical rib-fins and brackets of the tank with the load distributed over the ring wall by the skirt plate.

Tunnel and Gauge House. Integral with the ring-wall, floor slab and gauge-house foundation walls is a pipe tunnel extending under the tank. This contains the inlet and overflow pipes. The roof and sides of the tunnel, including the gauge-house foundation walls are membraned water-proofed. The gauge house is constructed with reinforced concrete foundation, walls, and floors, salt-glazed brick, glass block panels, metal framed doors and windows, and insulated specification roof. The building houses the recording and transmitting instruments, telephone, tools, hot-air oil heater and the police radio quarters at one end, reached by an outside door.

Tank. The tank, spheroidal in shape, is 90 ft. in diameter at the equator and 47 ft. in height above the floor, with the overflow 12 in. below the roof. It consists of bottom and shell plates, the latter comprising curved plates of uniformly changing radii, of copper-bearing steel, electrically-welded in place. Vertical rib fins rest on brackets and are segmental in shape to conform to the shell contour. They are 32 in number, spaced at regular intervals around the tank and welded directly to the shell and skirt plates on which they rest. These segments extend well above the equator and transmit vertical loads direct to the skirt on the ring-wall, at the same time retaining the shape of the tank when empty. Joints of the shell plates are horizontal and vertical. The skirt plates and brackets are secured to the ring wall by anchor bolts.

Shape. The shape of the tank is that which a flexible container, filled with water, would assume when placed on a horizontal plane, not unlike that of a tomato. It is streamlined and certainly hurricane proof.

Economy and Design. By designing a rigid tank to the natural shape of a flexible container, economies are effected in that the minimum amount of metal is required to retain shape, since the shape is

that which would be taken if no stiffeners or supports were used. In other words, the design starts at scratch. All of the shell and bottom plates are placed in tension. Since the Brookline supply is taken from the ground, it is necessary to cover the storage container, whether it is a tank or a reservoir. In the customary cylindrical tank, a wood roof generally accomplishes this purpose, whereas in the case of a spheroid, the roof and shell are integral and one.

Plate thickness are as follows:

Bottom plates	3/8 in.
Bottom plate to skirt plate	13/16 in.
Skirt plate to equator	5/16 in.
Equator to top	1/4 in.

Preparation of Plates. After rolling and forming at the Greenville, Pa., mill, the plates were first dipped in large tanks containing a warm solution of sulphuric acid in which they were allowed to remain for a sufficient time to remove mill scale; next they were soused twice in warm water baths to remove the sulphuric acid; finally they were dipped into a phosphoric acid bath to which a small amount of iron had been added, thus leaving a thin coating of iron on the plates to act as a rust inhibitor and improve the bond between the metal and the paint. After removal from this final bath, the plates were hung in special racks where they were coated with a special paint while warm. In this manner there was no chance for film or dirt to collect, and the plates could be painted when erected; otherwise, sandblasting and scraping with several months of waiting for the mill scale to rust off, would have been necessary. As a result of this treatment, a longer paint life and reduced maintenance costs should result.

Erection. By the use of an erection "buggy" or fabricated steel staging on wheels, the rib fins were placed, guyed and tack welded, after being properly plumbed and spaced. Next the first section of shell plates was tack-welded to the fins and starting plates. Then the second section was secluded in a similar manner. By an ingenious wedge lock the plates were also secured to each other at the seams, thus holding to the designed contour.

Welding. The board at the outset, decided on strict compliance with the standards set up by the code of the American Welding Society. Applicants for the welding work, 165 in number, were required to take the wedge and wafer test. Only 4 were passed by our inspector unconditionally for seam welding and 5 could be used on

tack welding and chipping. All welders were required to show evidence of continuous welding for the previous six months.

State Authorities. The State Department of Labor and Industries requires contractors on public work to employ only citizens of the Commonwealth. As a result of our inability to qualify welders under such restrictions, the work was delayed nearly 6 weeks, until satisfactory arrangements had been made to import qualified welders from New Jersey. Normally, the erection of the tank should have been accomplished in 5 to 6 weeks' time, after the delivery of the steel to the site.

Power for the welding was furnished by a battery of 10 portable gasoline generators. The bottom and curved starting plates were first tack-welded to position. The final, or roof, plates were left off for lighting and ventilating, also for purposes of interior construction. In all cases, the "buggy" was used. Surmounted on this was a short boom derrick, operated by a compressed-air motor.

Exterior work on the tank such as welding, wedging, chipping, and cleaning was done from stagings placed at will on brackets welded to the shell. One could see a staging in one location and a few moments later on another section of the shell, always resting on brackets, tack welded to the tank. After the roof plates had been assembled and the tank welded, the "buggy" was dismantled and pushed out piece by piece through the manhole at the bottom.

Furnishings. The inside of the tank is furnished with a catwalk slightly above the equator and a davit to swing the manhole cover. Welded to the shell is a 16-in. by 16-in. steel box, extending from the top of the tank to the overflow outlet at the bottom. The top is fitted with a splash pan to prevent the air-activated overflow water from gushing out through the vent hole. The tank inlet and outlet opening is at the bottom to which is attached a 6-in. mud-sill.

A revolving ladder is hung from the finial of vent cap by a special swivel, and the ladder, shaped to the shell contour, rests on 6-in. steel wheels against the sides. There is a removable 12-ft. straight extension at the bottom. At the top is the finial and screened vent cap and a 30-in. by 30-in. trap door, readily reached from the ladder. To facilitate inspection and painting inside the skirt plate, two manholes are provided.

Superimposed on the vent cap is a 30-ft. police radio mast, guyed to lugs welded to the tank shell. Reinforcing angle-irons are welded to the bottom of the roof plates under this cap to carry the additional load and prevent weaving of the plates by wind load on the mast.

Painting. Unpainted edges of the bottom plates were thoroughly cleaned, and the bottom faces of the plates were painted with 2 field coats on arrival. Strips of heavily impregnated and coated asbestos were laid on the foundation material under each seam, and an application of corrosion preventive with which the strips were impregnated was poured on the strips just before laying the plates. No further field painting was done until the welding had been completed and the tank tested for leakage. All chipping and scraping were done, both inside and out, before the leakage test, after which both sides of the structure, including the top of the bottom plates, were cleaned by revolving wire brushes and other means, including gasoline for removal of grease and oil. All welds and chipped surfaces were spot-painted. Then, first and second coats were applied by hand brushes. Restrictions in regard to temperature and humidity were carried out as were requirements for brush sizes and the "boxing" of paint before using.

The shop coat, mentioned before, consisted essentially of dry red lead, raw linseed oil, turpentine, drier and litharge. The first field coat was practically the same as the shop-coat with the exception that it contained 24 lb. of dry red lead per gallon instead of 33 lb. as required for the former coat. Lamp black and French ochre were also added. The second field coat contained white lead (basic carbonate), raw linseed oil, turpentine and drier, to which had been added litharge and boiled linseed oil just before using. This coat was tinted with lamp black and French ochre to distinguish it from the prior coat. For the exterior coats the same procedure was followed as for the inside coats with the exception that no litharge was used. The final coat is light gray in color and blends with the sky line. Paint was used on the day on which it was mixed. All ingredients conformed to the specifications of the American Society for Testing Materials, and a certificate to that effect was required.

Bonding and Guarantees. All contractors furnished a 100% completion bond and evidences of proper insurance coverage. The tank contractor was required to furnish a 100% five year maintenance and guaranty bond against structural and paint failure.

Tensometer Test. Briefly stated, this test was conducted by Professor John M. Lessells of the Massachusetts Institute of Technology with Professor Chas. M. Spofford and Mr. E. B. Myott of Fay, Spofford and Thorndike computing the strains measured in the field by the tensometers. As a result of these tests which were made

simultaneously at five points on the shell from top to bottom, as the tank was filling, the maximum stress computed from the strains measured by the instruments equalled 10,600 lb. per sq. in. tension and occurred at the equator with the tank full. The theoretical maximum stress at this point, as determined in the design computation, was 10,800 lb. per sq. in.

Specifications required the steel plates to conform to standard specifications A-10-34 of the American Society for Testing Materials for copper-bearing steel plates, namely 55,000 to 65,000 lb. per sq. in., with a yield point equal to one-half the ultimate strength. Tests conducted by Mr. Conard at the mill gave a minimum ultimate strength of 58,520 lb. per sq. in. and a maximum yield point of 35,730 lb. per sq. in. Therefore, according to this information, the maximum stress is only 30% of the yield point and 18% of the ultimate strength, resulting in a safety of factor much in excess of that generally allowed for railway and highway bridges, where allowable stresses are based on 15,000 lb. per sq. in.

Landscaping and Grading. Due to the residential character of the neighborhood and our desire to maintain a pleasing sky line, considerable care was given to set up an effective screen of foliage. Coniferous trees from 10 to 40 ft. in height were transported from Holliston, Mass., and placed at pre-determined spots, in accordance with plans made from perspective photographs. Later, under-planting was completed, and the grounds were graded, loamed and seeded. Retaining walls and an asphalt driveway were also constructed.

A chain-link fence, 10 ft. in height, surrounds the tank. Against the ring wall is an 18-in. dished gutter, connected to the four quadrant catch basins, to carry off rain, melting snow and condensation. Between the fence and the gutter is a pea-stone walk.

Under normal weather conditions the tank is hardly visible against the sky-line from the adjoining properties and nearby hills.

Results. Depending on the growth of the town served by our high-service system, the tank should meet normal demands for several years, after which the erection of a similar and larger tank, on the same hill or one of the hills nearer the center of demand, will be necessary.

For the present, however, pressures have increased from 6 to 12 lb. per sq. in. on the elevations, where, heretofore a negative residual pressure of 8 ft. had been noted at a hydrant to which a 1000-g.p.m. pumper had been attached.

Cost. The cost of the work was as follows:

Tank	$38,750
Gauge House, concrete work, etc.	22,300
Planting, landscaping	11,000
Grading and walks	2,800
Pipes, gates and checks	14,600
Instruments, gauges, lines, etc.	900
Removal of old structures	1,400
Miscellaneous and fees	4,050
Total	$93,800

SOME PHASES OF PUBLIC RELATIONS

BY HAROLD L. BRIGHAM*

[*Read September 15, 1939.*]

In considering this subject I am going to deal principally with the small or medium-sized municipal water works. There is no question but what the public relations problem is one that is faced by every business today; and the municipal water works, regardless of the size of the community, is no exception. Of course, the larger the community the more complex the problem; but still, I believe, that the same basic principles can be applied in nearly all cases. In my opinion, the three basic principles are *courtesy, common sense, and the Golden Rule.*

First we must remember that, if we are to meet the public well, we must be well met ourselves, and the first problem is to pick out and train the personnel of the department that it may meet the public well and in so doing sell the department to the public. It is not necessary that the person be of the high-pressure sales type or even of the sales type at all. Some persons have the faculty of being easy to meet and others do not. Much care should be taken in selecting those whose regular duties entail constant contact with the customer. There is no hard and fast rule that can be laid down for the approach to all customers. Some will be pleasant to deal with, ready and willing to accept without question whatever information may be given; others may be the exact opposite: they must be shown. If the customer is right in his criticism or complaint, he should be told so, for the customer is always right, until he is wrong, in which case he must be diplomatically shown where he is wrong without getting into an argument or dispute in the matter. It has been my experience that any two reasonable persons can come to an agreement; that we should listen carefully to the customer's side of the story and give it as much consideration as he gives to our side of the story, perhaps in the beginning a little more so. There are certain persons who feel they have a God-given right to take all municipal employees over the coals, regardless of whether they are doing a good job or not; but it is again my experience that the public does not object to paying

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for service if it gets a run for its money. For instance: if we are to relay a service for a customer, who, we shall assume, has a beautiful lawn that must be taken up, we may find that he does not object to paying a dollar or two more for the cost of relaying this service if pains are taken to replace his lawn in as reasonably good a condition as we found it.

Municipal water works are not operated for a profit in the same way as a private company might be, although the water takers are in a sense the stockholders in a public utility and the dividends to be paid must be paid in service rather than in cash. In most cases the water taker is paying a premium over and above his tax rate for water service, and the rate is usually comparable to the rate of private companies. Therefore, the municipal water works should render more service to the customer than a private company. There is another factor to be taken into consideration, namely, that when you render some small service or some small favor, it may seem small to you, but to the customer it may be of some moment. On the other hand, he may be the one who is going to sit in judgment on your budget at the finance committee meeting or he may have a vote in the town meeting that you may need at some time.

All employees should use extreme courtesy both in attitude and conversation when dealing with a customer or with any individual, and if they should be asked a question the answer to which they do not know, they should be frank in telling the customer or the individual that they do not know the answer but will find out. They should then make it a business to find that answer and see that the customer gets the information desired. If we make a real effort to see the customer's side of the complaint, I think we have gone a long way toward solving that complaint, because we then have a picture that shows both sides of the question or complaint. The water works man should, of course, be familiar with the water works side of the picture before he gets the customer's side.

No complaint is too small to be promptly investigated, even though it may seem trivial and seemingly needless. The trivial and seemingly needless courtesy that the department performs may pay big dividends in the form of public "Good Will" that can be obtained in almost no other way.

Another item that is very important, I believe, is to keep our plant, offices, buildings and grounds clean and neat and in as good condition as possible within our budget allowance. A well-painted

office, pumping station, or a well-kept lawn and trucks, or other equipment, kept clean and painted are not expensive, and they have a psychological effect on the public. See to it that truck and automobile drivers show courtesies to the drivers of other vehicles and to pedestrians in particular. Since the department's name is painted on the machine, it is a travelling advertisement, and a second or two spent to let some person or child cross the street safely or giving another vehicle the right of way increases the public's respect and "Good Will". It is also important to take time to show an interested customer the plant or office, to explain in detail how a municipal water works functions, remembering always that a satisfied customer is a booster for the water works. The fact that a municipal water works, as a rule, has no competition is apt to make the public somewhat suspicious of the utility. Talks before civic organizations, service clubs, and school children, I believe, are important. The school children are especially important, for the pupil of today is the tax payer of tomorrow. He should be told the story of an adequate water supply, also the story of what has been done, what is now being done, and what is hoped to be done. Don't forget your local newspaper man, and if you have any news that concerns the water works be sure that he gets the news correctly from you. Copies of a story of the department, telling what it does and how it functions, for the use of the students in the high school and other institutions, are helpful. Readable annual reports that do not contain too much tabular matter, which, while it may be of interest to water works men, is of no special interest to the customer, are also valuable. Do not let the public forget that the municipal water works represents a large investment of public funds, that it is operated entirely for their benefit, and that, actually, water works operators are guardians of the public health.

All this may be sort of a rambling talk, but what I am trying to bring out is that it is not so much any particular thing that may be done but everything that is done that affects the public and has a very decided bearing on the public's attitude and "Good Will".

If, as I said in the beginning, we practice courtesy, common sense, and try to treat the public in the same manner as we ourselves would like to be treated under similar conditions, we have, I believe, gone a long way toward solving the public relations problem of a municipal water works.

Summary of Discussion

Leland G. Carlton (Springfield, Mass.) called attention to the method of avoiding complaints of high water bills and checking drop in consumption by intervening readings of meters and notification of the consumer. The use of postal cards for billing purposes was then discussed and Sidney S. Anthony (Augusta, Me.) remarked that U. S. Postal Regulations prohibited the use of post cards for anything but current bills. Percy A. Shaw (Manchester, N. H.) mentioned the practice of reducing abnormally high bills when the consumer can show that he has used reasonable care in attempting to control waste of water by leakage.

NEW PRIMING SYSTEMS FOR USE WITH CENTRIFUGAL PUMPS

BY FRANK S. BROADHURST*

[*Read September 14, 1939*]

The desirable suction arrangement for centrifugal pumps is to have the pump installed at a grade that permits the water to flow int the pump casing by gravity. This eliminates all problems, as far as pump-priming is concerned, and the provision of a simple automatic air-relief valve insures that the entire pump is filled with water at all times.

Unfortunately, however, it is rarely possible to so place the pumps without involving large expenditures for excavating, waterproofing, etc., and in nearly all cases it is necessary for the pumping equipment to be located at a grade above the suction grade and for the pump to "draft" its supply. Provided that the suction is not excessive and the pump manufacturer is fully informed as to the maximum suction lift that will be experienced, this arrangement is not objectionable. As compared to the submerged-pump arrangement, it has many advantages, including better accessibility, simpler piping and easier draining when overhauling. However, as I have just pointed out, the physical impossibility or high cost of lowering the pump-foundation grade generally requires the pump to be located at a point requiring a suction lift.

Facing, therefore, these facts, it became evident to me that the obvious solution was: "if you cannot lower the pump, then the best thing to do is to raise the water above the pump". Acting on this theory, during the last ten years, I have installed a number of centrifugal pumps with a suction arrangement that I term "the submerged suction priming system".

The general idea is in all cases to lower the absolute atmospheric pressure on the surface of the water on the suction side of the pump, so as to cause this water to be continuously maintained at an elevation sufficiently above the suction openings of the pump impeller. This keeps the eyes, or suction openings of the impeller, sealed at all times against the entry of air, and the unit is then posi-

*Turbine Equipment Co. of New England, Boston, Mass.

tive in action, will always pump as soon as the pump gets up to speed, and, so far as the operator is concerned, no priming attention is needed at any time.

This is the basic principle, but there are a number of other features that come into the picture. Questions of removing entering air to prevent possibility of loss of suction while in operation and the equally necessary features of gland sealing, type of pump-discharge check-valve, possible necessity for priming while running, and other points that time will not permit me to cover as I would like to.

Working strictly along the lines indicated, that is to elevate artificially the suction supply above the pump, I have designed and built a number of systems to suit many different pumping conditions in connection with horizontal and vertical pumps, both of the single and multistage type.

In connection, however, with the water works pumping there are only three of these systems that usually apply, and I propose to describe these in some detail.

Figure 1 shows an extremely simple, unit type, submerged suction, priming system designed to maintain one pump continuously filled with water. It may be noted that, with some few exceptions, all systems I have designed are intended to keep the suction line, priming chamber and pump, or pumps, filled continuously. That is, the first filling of the suction line is the only filling and all pumps are maintained always ready for immediate service unless they are in the process of overhauling or adjusting.

The picture shows a single-stage centrifugal pump with horizontally divided case. Above this is mounted a rectangular box-like casting connected to the top of the pump-suction bells by the concentric priming-pipes shown. The larger pipes connect only to the bottom of the box and the smaller or central pipes extend to nearly the top of the priming chamber and also down through the pump-suction bells. The other items are a waterjet eductor, or air pump, a solenoid valve controlling the pressure-water supply to this eductor, a swing check-valve connected to the eductor air-suction, two insulated electrodes and an induction relay.

When this pump motor and priming system are energized either by closing the main motor starter or by closing this starter and a supplementary priming-system service, the immediate action is to open the solenoid operating the water-pressure valve and this water flows to waste from the water-jet, air-pump discharge indicated in

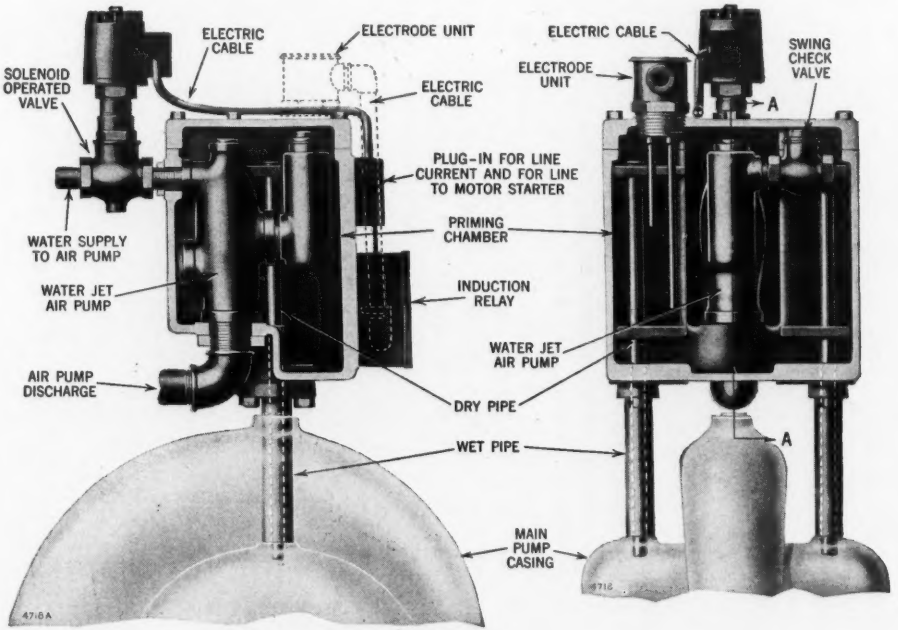

FIG. 1.— A SIMPLE UNIT-TYPE SUBMERGED SUCTION PRIMING SYSTEM FOR ONE CENTRIFUGAL PUMP.

the left hand view. Considerable volumes of air are immediately aspirated or withdrawn through the swing check-valve from the priming chamber, pump case and the suction line, that is, the entire pumping system up to the pump side of the water-discharge check-valve (not shown on this picture) are rapidly exhausted below atmospheric pressure. This reduction in absolute pressure on the surface of the water in the suction main causes it to rise and to fill the pump and the priming chamber. In this connection note that it is not necessary to make provision to vent the discharge volute. Priming on the discharge volute, as frequently adopted, is, in my judgment, a mistake and for several reasons, one of the most important of which is that as soon as the pump is primed such devices are immediately exposed to full discharge pressure. This necessarily affects the design of these parts and further eliminates what I term "continuous priming"; this of course for the reason that a volute primer is locked shut by the discharge pressure and it is not, in my experience, physically possible to remove air and maintain the pump primed in this manner while the pump is in operation. This, of course, only refers to cases where extraordinary air leakage develops, which rarely occurs in a water works with the single exception of pumping driven-well fields (quite common in New England), and about which I shall have more to say a little later.

By ignoring the conventional priming opening on the top of the pump volute and regarding this water as having passed the pump and being of no further interest to us, from the standpoint of the priming system, we achieve features by submerged-suction priming-equipment, connected only to the suction bells of the pump, that cannot be secured by discharge volute primers. I repeatedly use the words "pump primer" because it is the conventional and best understood phrase, but I would again point out that all the systems used by me depend entirely upon holding the water supply level at a point above the pump suction. The pump then fills and remains filled with water and is thus truly self-priming, but not perhaps according to the conventional idea of a priming system such as heretofore employed by many pump users.

Continuing the discussion of the operation of this unit-type system, the electrical connections are such that when the water level in the priming chamber submerges both the lower and upper electrodes, the circuit to the solenoid valve is broken and the valve is spring-closed, shutting off the pressure water to the eductor. Air

then rushes back through the eductor and closes the swing check-valve, and the water completely fills the pump, priming chamber and all parts up to the swing check-valve. The main pump motor is then started, either manually or by automatic control such as altitude switch, pressure switch, or float control. It should be noted that there is a tie-in between the induction relay and the starter for the main motor that does not permit this motor to start unless the water in the suction chamber submerges both electrodes. Similarly, if, due to excessive leakage, a closed suction valve, a plugged suction strainer, or other unusual causes, the level should drop in the suction chamber below the lower electrode and leave these electrodes not submerged for a period of 30 seconds, then the main motor will shut down and cannot be restarted until the difficulty has been corrected and the normal water elevation in the priming chamber again attained. This fully protects the pump case and impeller wearing-rings, shaft sleeves, and other parts that would be injured, if the pump ran dry for any length of time.

During the normal operation of the pump, with average air infiltration into the pump suction pipe, stuffing boxes, etc., there should ordinarily be a slow lowering of the level in the priming chamber. This is generally occasioned by the fact that some of this entering air leaves the stream of water in the suction bells, passes up the two larger of the concentric pipes and is collected in the top of the priming chamber. This does not happen, however, with this system, for the reason that the smaller priming pipes are so designed that, when the pump is in operation, an aspirator action is established that exhausts the pocket of air remaining in the top of the priming chamber until water rises above these small pipes and seals them off. This higher level is maintained during the time the pump is in operation.

After the pump has been shut down, there will be a gradual collection of air in the top of the priming chamber, but, as soon as this air uncovers the lower electrode, the waterjet air-pump, or eductor, goes into service, and in a few seconds both electrodes are again submerged. By this arrangement it will be seen that "the pump has a continuously submerged suction" and this without regard to the length of the suction line or whether the suction lift is high or low. Therefore, at all times as soon as the pump starts up, pressure is developed and water is delivered without any attention on the part of the operator as to whether the pump is "primed or not".

Figure 2 shows an arrangement very similar to Figure 1, with

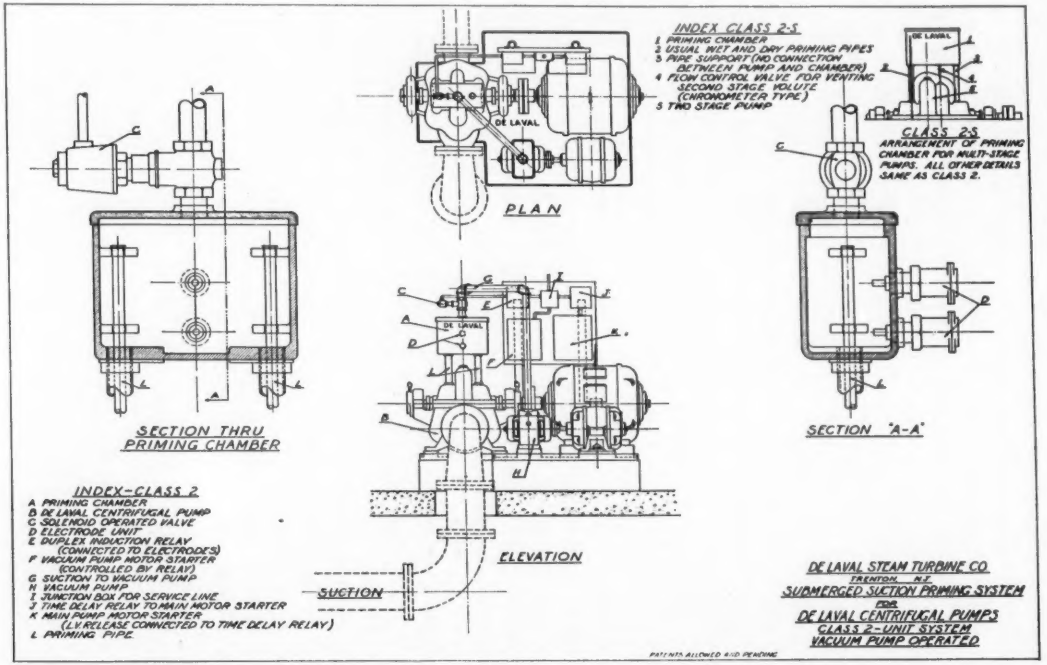
INDEX CLASS 2-S
1 PRIMING CHAMBER
2 USUAL WET AND DRY PRIMING PIPES
3 PIPE SUPPORT (NO CONNECTION BETWEEN PUMP AND CHAMBER)
4 FLOW CONTROL VALVE FOR VENTING SECOND STAGE VOLUTE (CHRONOMETER TYPE)
5 TWO STAGE PUMP
PLAN
CLASS 2-S
ARRANGEMENT OF PRIMING CHAMBER FOR MULTI-STAGE PUMPS. ALL OTHER DETAILS SAME AS CLASS 2.
SECTION THRU PRIMING CHAMBER
SECTION "A-A"
ELEVATION
INDEX-CLASS 2
A PRIMING CHAMBER
B DE LAVAL CENTRIFUGAL PUMP
C SOLENOID OPERATED VALVE
D ELECTRODE UNIT
E DUPLEX INDUCTION RELAY (CONNECTED TO ELECTRODES)
F VACUUM PUMP MOTOR STARTER (CONTROLLED BY RELAY)
G SUCTION TO VACUUM PUMP
H VACUUM PUMP
I JUNCTION BOX FOR SERVICE LINE
J TIME DELAY RELAY TO MAIN MOTOR STARTER
K MAIN PUMP MOTOR STARTER (LY RELEASE CONNECTED TO TIME DELAY RELAY)
L PRIMING PIPE
SUCTION
DE LAVAL STEAM TURBINE CO.
TRENTON, N.J.
SUBMERGED SUCTION PRIMING SYSTEM
FOR
DE LAVAL CENTRIFUGAL PUMPS
CLASS 2-UNIT SYSTEM
VACUUM PUMP OPERATED
PATENTS ALLOWED AND PENDING

FIG. 2.—DETAILS OF UNIT SYSTEM OF SUBMERGED SUCTION PRIMING SYSTEM FOR CENTRIFUGAL PUMPS, VACUUM PUMP OPERATED.

the exception that air removal is accomplished by means of a motor-driven, dry vacuum pump, in place of a water-jet eductor. The electrodes in the priming chamber control the solenoid air valve and the starter for the vacuum-pump motor by means of the induction relays previously referred to. When putting the unit into service, the vacuum pump rapidly evacuates the suction line, the pump casing and all parts up to the discharge check valve. As soon as the water submerges the upper electrode, this operates the induction relay which breaks the circuit to the solenoid valve; this closes; and, at the same time, the circuit to the vacuum-pump starter is broken, and the vacuum pump shuts down. As soon as the main unit starts up, the priming pipes extending into the suction bells proceed to evacuate still further the top of the priming chamber, until they are submerged and water flows downward. This action is exactly the same as before. Should excessive air leakage, however, cause the level in the chamber to fall below the lower electrode, then the vacuum pump will restart and the solenoid valve will be opened. If this action is not sufficient again to fill the priming chamber to the level of the upper electrode within thirty seconds, the connection to the main pump-motor starter (that is, the low-voltage release coil) is short-circuited and the driving motor shuts down. This is necessary to avoid danger of injuring the pump if it should run unprimed for any appreciable length of time. Here again, the continuous submerged-suction arrangement is employed; that is, when the main pump unit is not in operation, the vacuum pump, electrodes, etc., are still energized as required, and the priming chamber is kept full of water, so that the main pump is always maintained with flooded suction ready for instant operation.

Figure 3 is more desirable in some water works pumping stations than the unit systems just illustrated. It is primarily intended for a pumping station with two, three or more pumps, and the idea is to furnish a central vacuum reservoir and to connect this vacuum reservoir to suitable priming chambers on each of the pumps. This makes a central system that is somewhat simpler than several unit systems, as it reduces the number of vacuum pumps, switches, etc. and provides a considerable reservoir of high vacuum, available for quick priming of any pump, or pumps. Furthermore, such an arrangement is less costly for three or more pump units than individual unit primers would be.

First with regard to the vacuum reservoir: this is a suitable tank, generally horizontal and cylindrical, fastened to a wall or from roof

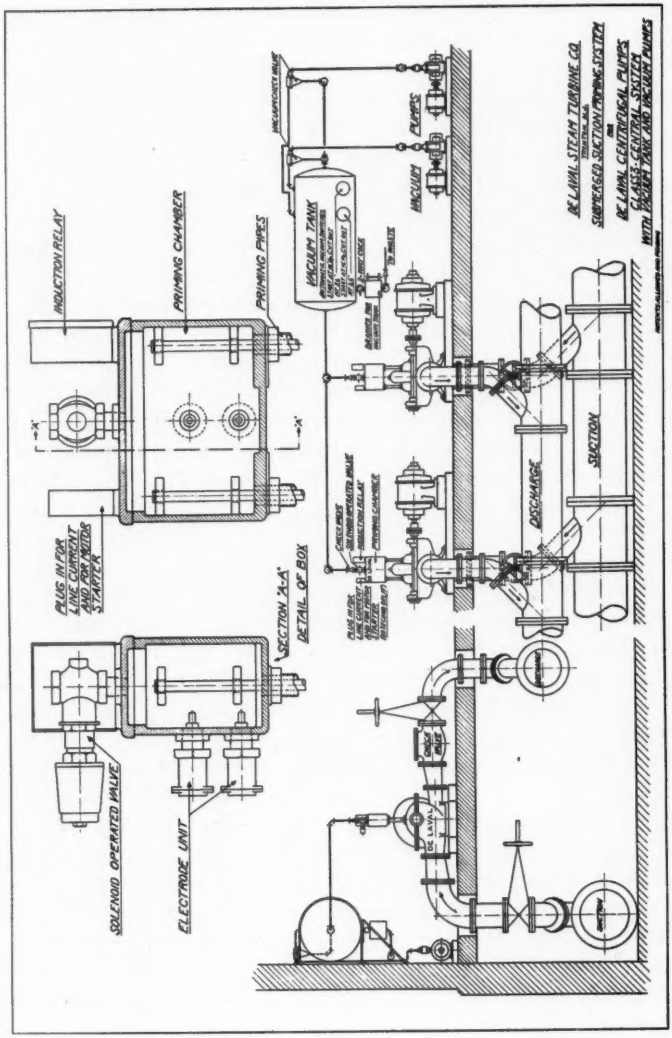

FIG. 3.—A CENTRAL SUBMERGED PRIMING SYSTEM FOR TWO OR MORE PUMPS.

beams and provided with a simple hand-operated drainer and sight glass, so that any condensation that collects can be periodically removed. The vacuum is secured by means of two motor-operated, direct-connected vacuum pumps of the sliding-abutment, oil-sealed and lubricated type, and these are controlled by diaphragm switches connected with the tank. The pumps are set to operate in sequence with a transfer switch to change the leading pump, week by week. Other details are the special vacuum check-valves in the pump-suction lines, which I have found to be absolutely tight in contrast to the swing checks commonly used, which are far from vacuum-tight in this service. This system of tank, vacuum pumps and accessories, guarantees that a vacuum reservoir will be continuously maintained, generally at a minimum vacuum of 18 in. and a maximum vacuum of 26 in.

Each of the pumps is equipped with a priming chamber similar to that of the previous illustration, but without the waterjet air-pump. The chamber is shown in section and carries two electrodes and the same arrangement of concentric priming pipes. The connection between the vacuum tank and the chamber is through the solenoid valve shown, which is operated by the electrodes through the induction relay also shown.

The method of operation is very similar to that of the previous equipment. As soon as the priming system is energized, the two vacuum pumps, operating in parallel, build up the vacuum in the tank and, as all solenoid air valves are then energized and open, the entire suction system, all pumps connected thereto, and the pump discharges up to the check valves are immediately exposed to the rising vacuum in the vacuum tank. Within a short period of time, depending upon the size and length of the suction main, the entire pumping system is filled with water, and, as soon as the water submerges the upper electrode on each pump, the solenoid circuit is broken, this valve closes droptight and the pump is isolated from the vacuum tank. As soon as each pump starts up, the aspirator action in the central priming-pipes occurs, the water level is lifted until these pipes are submerged, and the water stays at that elevation during all the time that the pump is running, holding all electrodes permanently submerged. Should excessive leakage of air develop in the pump suction from any cause, the level in the priming chamber will fall until both electrodes are uncovered. The solenoid valve will then open and the high vacuum in the tank will promptly elevate the

water above both electrodes, after which this valve closes again. The pump has been operating without loss of prime during this period, but should air leakage be such that the level cannot be restored, the pump will run for thirty seconds and then shut down and can only be restarted by a hand reset on the starter after an investigation by the operator of the cause of the excessive air leakage. This feature is of great importance on large and costly water works pumps operating in automatic stations where a pump running dry for a short period can cause a considerable monetary loss, to say nothing of possible crippling of the service.

An interesting, and sometimes important, feature of this central, submerged-suction, priming system in water works and similar service, is that the pumps can be operating on different suction lifts. One or more pumps may have a relatively high suction lift, other pumps a very low suction lift; in fact, in some cases, pumps can operate during certain periods with a suction head or positive pressure on the suction and at other times with a varying suction lift. This feature is sometimes of value in connection with filtration, iron removal and other treatment plants where prevailing grades usually require different lifts on different pumps. In some cases, where the raw water pumps draw from a river, extreme high and low water in the river will create considerable variations in the suction conditions for the raw-water pumps. This ability to handle any condition that arises within the capacity of the pump is of course due to the fact that the solenoid valve isolates the pump from the central vacuum reservoir and makes it truly a unit proposition.

Figure 4 shows the arrangement I have used in a number of cases for pumping a driven well field in various parts of New England. As I said earlier, this applies more to New England than any other section of the country with which I am familiar.

As will be seen, the conventional or so-called sand chamber is set vertically and is divided by a welded partition into two sections: the upper, or high-vacuum section, and the lower, or water and low-vacuum section. The upper section is constantly maintained under a condition of relatively high vacuum, generally by means of duplicate, motor-driven, rotary, dry, vacuum pumps, these pumps being controlled in the same way as in the previous systems discussed, by the use of diaphragm switches and a transfer switch to make either pump the leading unit. The object of this arrangement is to maintain in this upper or high-vacuum section a vacuum generally from

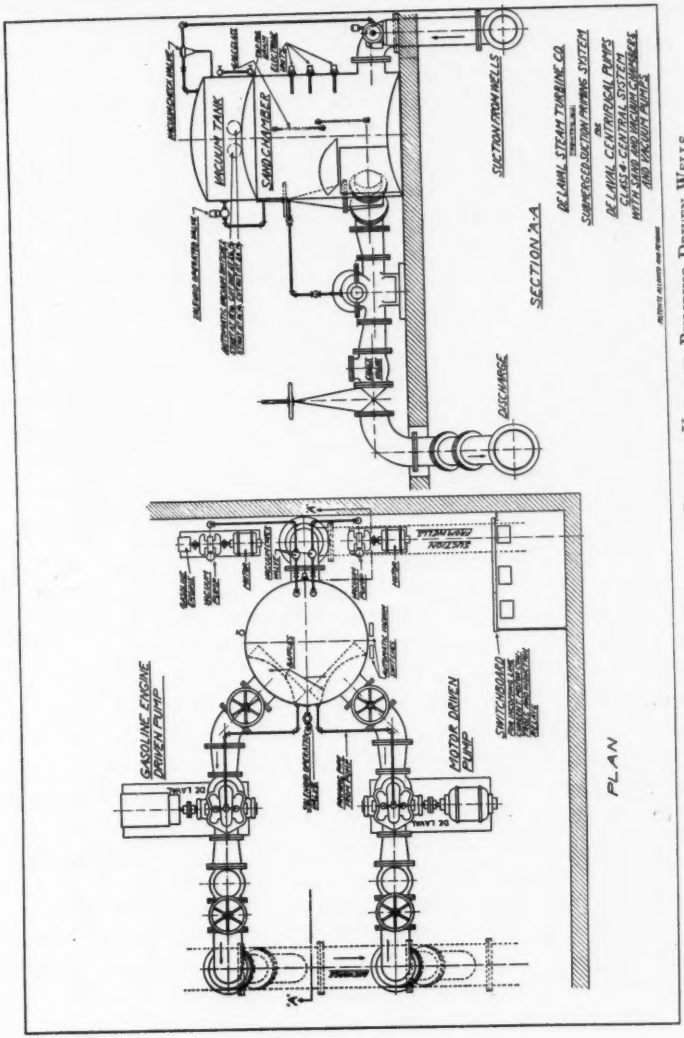

FIG. 4.—A SYSTEM OF SUBMERGED SUCTION PRIMING USED FOR PUMPING DRIVEN WELLS.

about 18 in. of mercury minimum to about 26 in. of mercury maximum. This is subject to some variation, depending upon the maximum suction-lift under which the pumping equipment will have to operate.

The connection between the lower, or sand chamber, section and the upper, or high-vacuum, section is made by means of a pipe of suitable size incorporating a solenoid valve. The opening and closing of this valve are controlled by electrodes located as shown in the side of the sand chamber at suitable elevations. It will be noted that the two upper electrodes control this solenoid valve through a suitable induction relay, the action being that when the water level in the sand chamber submerges both the lower and upper electrodes, this valve closes droptight. Similarly, when both electrodes are uncovered, the valve is wide open and the air space in the lower section of the sand chamber is then in communication with the high-vacuum upper tank. The other features of particular interest are: the bottom electrode which is entirely a low-water protection and, if this is uncovered, the low-volt release-coil of all the starters on all the pumps connected to the sand chamber which is short-circuited so that none of the motors can operate until this condition is corrected. The other important feature is the arrangement of the suction air-vents from the pumps which are connected above the upper electrode and which, due to the aspirator action previously referred to, causes any pump, or pumps, in operation to remove sufficient of the entering air to keep the water level in the sand chamber constantly at the level of this vent connection. I may add that this is a particularly important feature, not so much because it greatly reduces the operating periods for the vacuum pumps, but because it guarantees that all pumps operating on the system will always have the same submergence or height from the center of the pump shaft to the water level in the sand chamber. This feature has a very steadying effect on the amount of water pumped so that the flow meter will not show the considerable surges that I have noted on systems in which the water level is permitted to change between starting and stopping of the vacuum pumps. This arrangement has worked particularly well under some rather serious conditions, including considerable air leakage due to the use of old wells and pipe lines, and extremely high suction lifts during certain seasons of the year when the water table dropped considerably.

Figure 5 shows an installation made some eight or nine years ago for the town of Hanover, Mass. In this particular installation, the

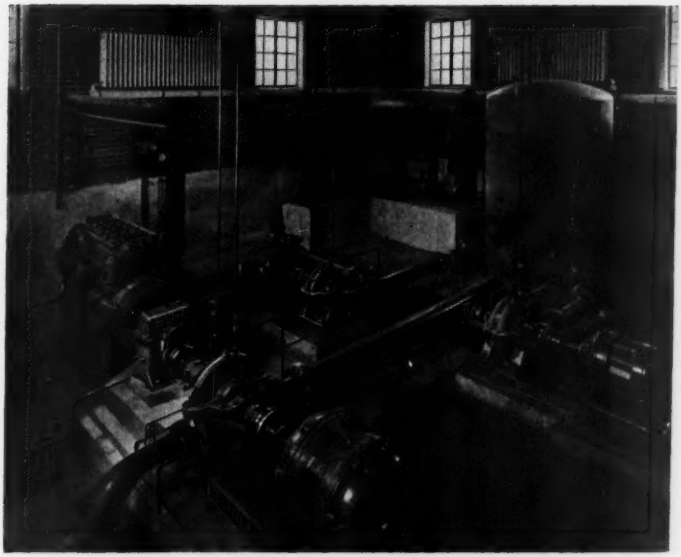

FIG. 5.—A SUBMERGED SUCTION PRIMING SYSTEM IN HANOVER, MASS.

high-vacuum tank is located on the wall instead of being built in as part of the sand chamber. Three centrifugal pumps from the sand chamber, two being motor driven and one being driven by a motor and a gasoline engine through a step-up gear. An interesting feature also is that one of the vacuum pumps is gasoline-engine driven as well as motor driven, so that, in the event of failure of current, the gasoline-engine driven vacuum-pump can maintain the vacuum in the upper chamber, while the gasoline-engine driven main-pump is "drafting" the water from the wells and delivering it to the standpipe.

Figure 6 shows a similar installation to the preceding one, but in this case (as shown in the sectional view) the high vacuum tank is superimposed upon the sand chamber. The vacuum pumps are to the left against the wall and it will be seen that the two multistage water pumps take their suction from the sand chamber. This arrangement was installed at Reading, Mass., under the direction of Weston & Sampson, who were the consulting engineers for this plant.

In conclusion, I think this is a subject that has not heretofore been given enough attention. Many users of centrifugal pumps make

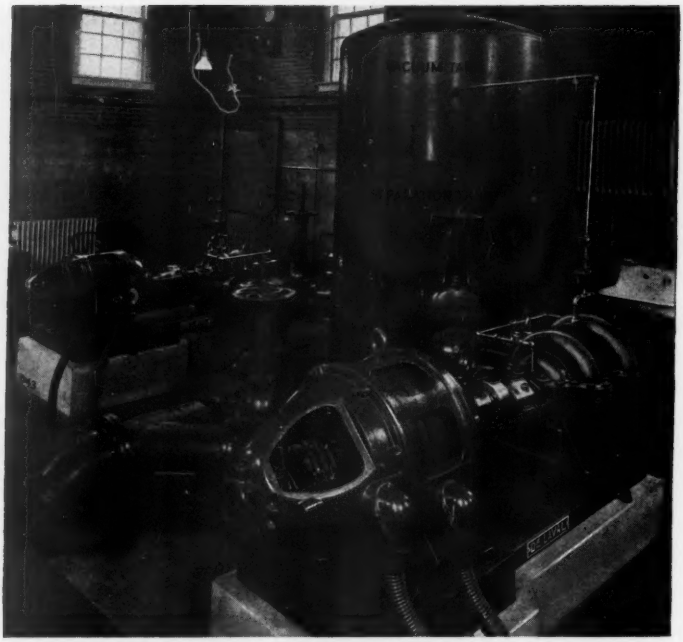

FIG. 6.—A SUBMERGED SUCTION PRIMING SYSTEM WITH HIGH VACUUM TANK SUPERIMPOSED UPON THE SAND CHAMBER.

no proper provision for priming, depending upon such obsolete and uncertain features as foot valves, hand-operated water-jet eductors, hand-controlled vacuum-pumps of various types and many home-made devices that generally accomplish the purpose, but require careful attention, are never automatic, and cannot be depended upon as a certain provision, particularly for automatic stations.

ONE HUNDRED YEARS OF PUMPING MACHINERY

BY S. W. KITSON*

[*Read September 13, 1939.*]

Early Water Works Pumping-Engines. It is recorded that perhaps the first major installation of water works pumping machinery in North America, was the Newcomen pumping engine installed in New York City shortly before the American Revolution. In the early 19th century, the few existing pumping engines were generally of the Cornish type, a single-acting Watt steam engine driving a series of pumps on one shaft, all operated by a single rod suspended from the end of the engine walking beam. These pumping engines were in effect the adaptation to water works practice of the mine-dewatering units developed from Newcomen's Atmospheric Engine Patents of 1705 and Watt's Basic Steam Engine Patents of 1769. Such machines, tremendous in size, costly to install and operate, were precluded from use on a large scale for water works service.

The First Direct-Acting Steam Pump, 1840. The year 1840 saw a great migration from the Eastern Seaboard to the newly opened lands of the Middle West. The whole country was transportation-minded and the state of New York, to expedite travel along its famous Erie Canal system, initiated a prize competition for new designs of steam-driven canal boats. Previous steam-driven vessels of this type were unsatisfactory for canal navigation, largely on account of difficulties experienced with the engine auxiliaries; the boiler feed-pump for instance, driven from the main engine shaft, was inoperative when the boat idled in locks, thus necessitating difficult and dangerous boiler feeding by a hand-operated pump.

A 23-year old engineer, Henry R. Worthington, submitted a boat design which received immediate acclaim. An interesting feature of its boiler plant was the feed pump which eliminated the necessity of hand operation at any time. This was the first, single, direct-acting, steam pumping-unit in history.

The pump was built with its cylinders in a straight line, with a single-acting plunger and a suitable steam valve. The customary

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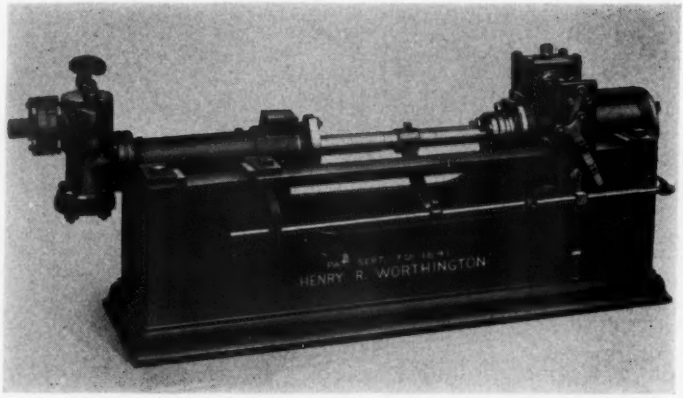


FIG. 1.—A REPRODUCTION OF THE FIRST SINGLE, DIRECT-ACTING STEAM PUMP.

flywheel was omitted. A pipe supplied the steam cylinder with steam from the boiler. The boiler end of this steam pipe was connected with a valve that was controlled by a float in the boiler. The float-actuated valve admitted steam to the pump's steam cylinder according to the height of the water in the boiler, thereby allowing the pump speed to vary according to the need of the boiler. Soon after the original design, a spring was added to the valve gear to insure more certain action of the slide valve.

The boat was a mechanical and engineering success, the worth of the direct-acting pump was immediately recognized, and this original pump was in use until 30 years later. As a transportation enterprise the vessel did not fare so well, and such was the opposition set up by existing towing companies and agricultural interests that, although the inventor was signally honored and granted a medal to commemorate his achievement, political pressure forced the boat into early retirement. However, this economic failure of a century ago revolutionized the practice of handling water, and undoubtedly gave the greatest impetus to the mechanization of water works plants since the invention of the steam engine.

The First Direct-Acting Water Works Pumping-Engine, 1854. The direct-acting pump, patented in 1844, was first manufactured about 1845; the initial units being sold for boiler-feed service in the marine field. The first direct-acting pumps sold for water works ser-

vice were for the city of Savannah, Ga., in 1854. This installation consisted of 3 compound, condensing, single, direct-acting units. Duplicates of these were sold to the city of Cambridge, Mass., in 1856 and 1857. The service conditions were 300,000 g.p.d. each against a 100-ft. head.

These Savannah-Cambridge engines had the high-pressure cylinder located inside the low-pressure cylinder and were equipped with square water plungers. At the top of the water cylinder was located a surface condenser through which steam from the engine was exhausted. Water, discharged from the pump, passed around and through this chamber to condense the steam. The air pump attached to the end of the main pump was horizontal.

The Duplex Direct-Acting Steam Pump, 1857-1859. The years 1857-1859 saw the development of the duplex, direct-acting steam pump, which has been called the greatest single contribution ever made to the progress of practical hydraulics. Experiments by H. R. Worthington in connection with water meters were indirectly responsible for the duplex water pump. The first American meter to come into general use, patented in 1855, embodied the principles of the duplex pump which was not patented until 1859. The duplex pump originally consisted of two single pumps placed end to end, with the steam cylinders together and with the valve rod of one operating the steam valve of the other. The design was soon modified to allow the side by side arrangement of pumps. The first duplex water works pumping-unit, which was of the compound type rated at 5 m.g.d., was installed in 1863 at Charlestown, Mass. It was sold under a very rigid guarantee reading as follows: "At least equal to that of any engine in the United States under penalty of removal in one year in the event of failure". The engine remained in service, and two additional units were ordered by the city within the following ten years.

Demand for Better Fire-Protection, 1862. The constant demand for improved fire-protection accelerated the installation of pumping engines by municipalities and assisted in bringing some degree of standardization, particularly to the crank and flywheel type.

In the year 1862, attention was drawn by the city authorities of Lockport, N. Y., to the matter of better protection against fire, and in the following year Birdsall Holly originated the system of direct-service water-supply and fire-protection which became widely known as the "Holly System." Its original idea was to provide fire protec-

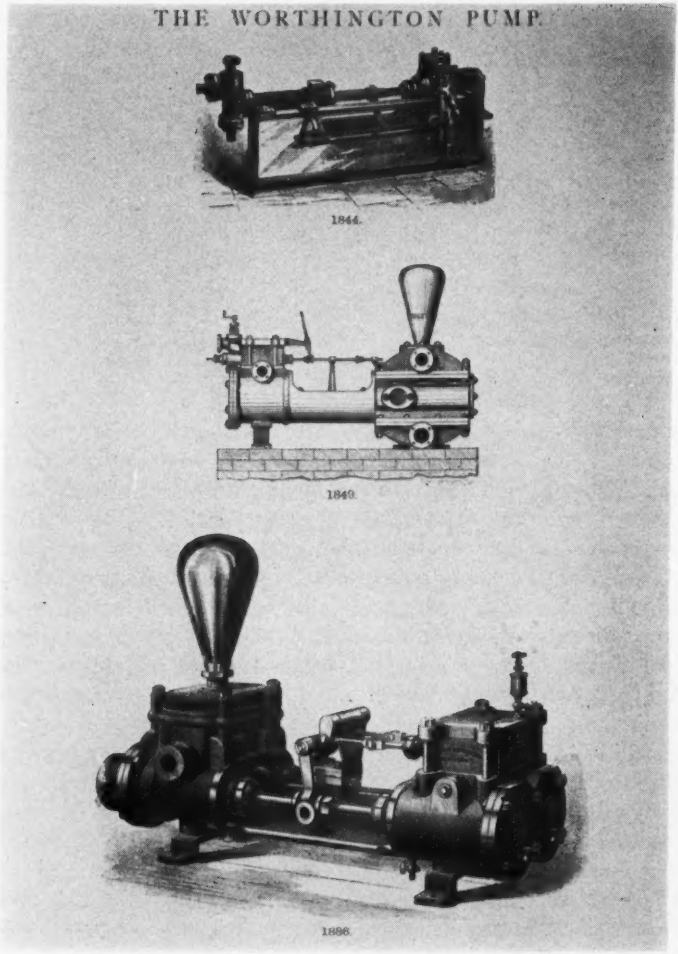


FIG. 2.—WORTHINGTON DIRECT-ACTING STEAM PUMPS.
STYLES OF 1844, 1849 AND 1886.

tion without the use of portable engines. Success in that service led to the combination of both domestic-supply and fire-protection through the same system of pipes, pumping directly into the mains without the use of standpipes or reservoirs. The feasibility of the combined service

was first demonstrated at the Auburn, N. Y., Water Works in 1866, and from that time grew in popular favor.

Civil War Activities. Due to the rapidly expanding market for pumps, several manufacturers entered the field during the Civil War Period, and in addition to the Cornish engines, the duplex, direct-acting type of engine received competition from various types of pumping engines of the compound, flywheel type. The direct-acting pumping-engine, however, in both horizontal and vertical sizes, retained its popularity for many years on account of its ability to distribute water without shock as well as its low initial cost as compared with other types.

High-Duty Direct-Acting Pump, 1884. In 1884, an improvement to the direct-acting pump, consisting of a compensating cylinder arrangement to assist in the completion of the stroke, prolonged its popularity and allowed it to compete on a fuel-consumption basis for several years with the more expensive, but recognized potentially high-economy crank and flywheel types, which were then being manufactured in both horizontal and vertical designs.

The first vertical, direct-acting, high-duty pump was installed in 1886 in the Cincinnati, O., municipal plant. This installation is associated with the first water works type of surface condenser, the latter located in the pump suction and utilizing the water pumped by

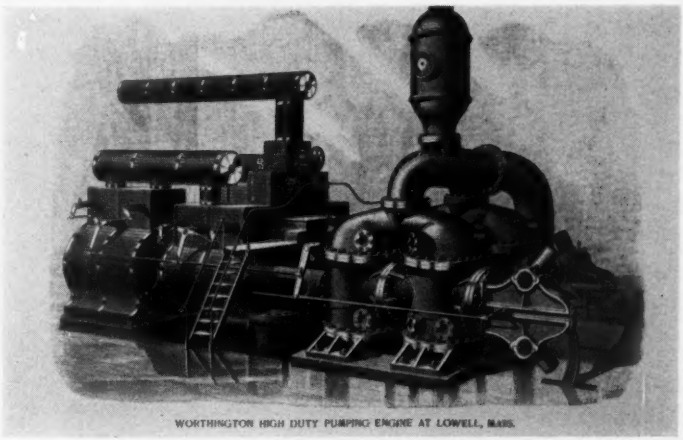


FIG. 3.—HIGH-DUTY PUMPING-ENGINE—DIRECT-ACTING TYPE—INSTALLED IN 1892 AT LOWELL, MASS.

the main unit to condense the steam that passed around the tubes. Prior condensers in water works pumping-engines were essentially of the jet type with attached air pumps operated from the main engine crosshead. Around 1900, surface condensers became very important items of water works engines, and huge cast-iron shells were frequent.

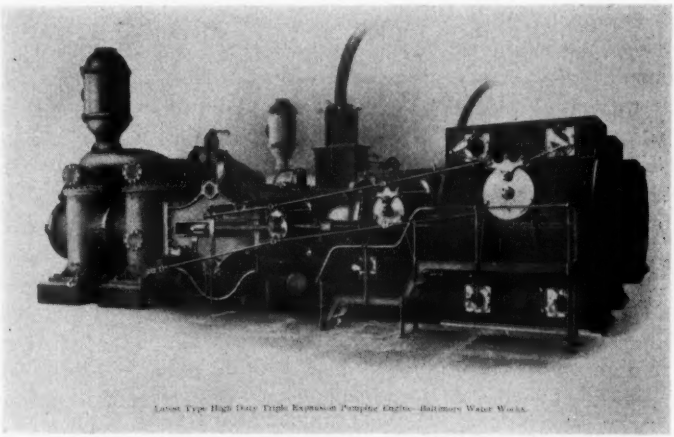


FIG. 4.—HIGH-DUTY PUMPING-ENGINE—DIRECT-ACTING TYPE—INSTALLED IN 1898 AT BALTIMORE, MD.

In spite of continued competition, as late as 1904, two of the largest vertical, direct-acting pumping-engines ever built came into existence. They were 27-in. by 42-in. by 45-in. by 60-in. duplex units and measured 62 ft. from foundation base to the top of the high-pressure steam cylinders. They had a capacity per pump of 40 m.g.d. and were capable of a duty of 175,000,000 ft.-lb. per thousand pounds of steam. They were installed, at Chicago, Ill., one at the Central Park Avenue Station and the other at the Springfield Avenue Station (Fig. 5).

Pumping Engines of the 1870's. In any review of types of pumping machinery, it is impossible to state definitely when any particular type gained the ascendency over another. The 1870's saw many unusual developments and considerable difference of opinion existed among water works engineering authorities as to the most suitable design for a given set of conditions. Many unusual flywheel machines

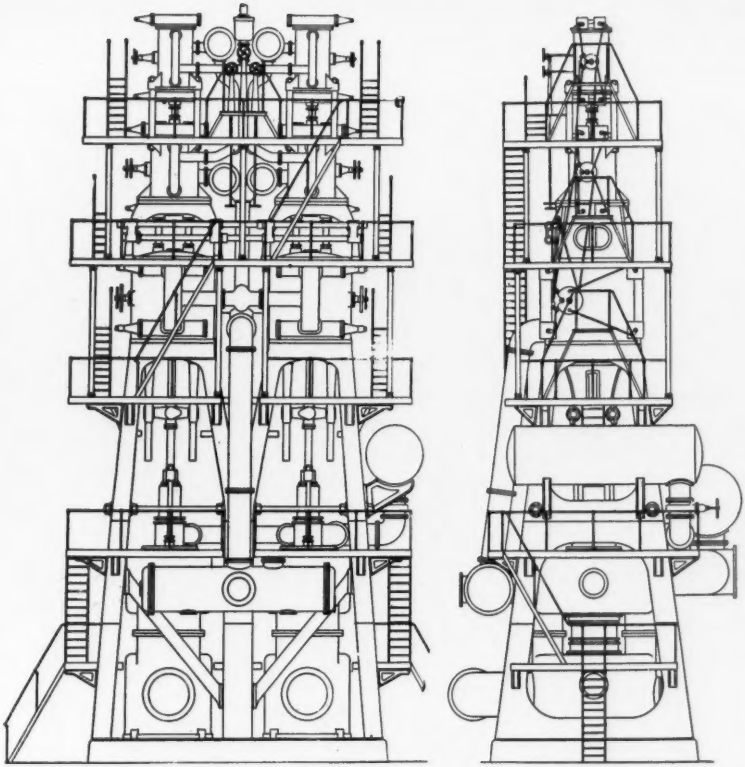


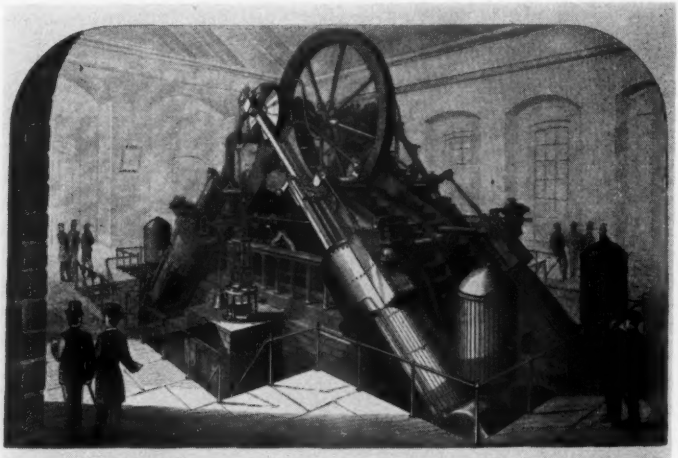
FIG. 5.—VERTICAL, DUPLEX, TRIPLE-EXPANSION, HIGH-DUTY, DIRECT-ACTING PUMPING-ENGINE—ONE OF TWO UNITS INSTALLED AT CHICAGO, ILL., IN 1904.

were installed in New England, including a Cornish engine at Providence, R. I., around 1870, also a 5-m.g.d. Corliss non-compound engine at Providence, R. I., around 1876. Compounding of cylinders became popular during this period, the first important water works example being the Schuylkill Plant installation at Philadelphia in 1872. In 1873 another type of compound engine designed by E. D. Leavitt was installed in Lynn, Mass., and equipped with both a walking beam and a flywheel. A Leavitt engine installed soon thereafter at Lowell, Mass., developed the exceptionally high duty of 103,000,000 ft.-lb. per thousand pounds of steam and was the first of the high-

duty-flywheel pumping-engines. It is evident that New England, early in the day, established itself as a "proving ground" for water works pumping-machinery.

Direct-Acting vs. Crank and Flywheel Pumping Engines, 1875. It was many times stated by engineers during the experimental days that "a pumping engine is a machine without a duplicate". By 1875, however, it was apparent that although the direct-acting pumping-engine had superseded the Cornish engine for water works service, the direct-acting machine itself was encountering stern competition from crank and flywheel pumping-engines. The latter steadily attained increased popularity, and a period ensued where water works lettings became vigorous contests over the relative merits of the two types compared as investments. Direct-acting condensing pumping-engines, with duties approximately of 60 to 70 million foot-pounds per thousand pounds of steam, with low first cost and established reputation, were pitted against the untried crank and flywheel type with what seemed exaggerated duties of 80 to 90 million foot-pounds, and correspondingly high first costs. At this time an initial steam pressure of 100-lbs. per sq. in. gauge was considered advanced practice.

The Holly Quadruplex Type of Pump, 1872. In 1872 appeared



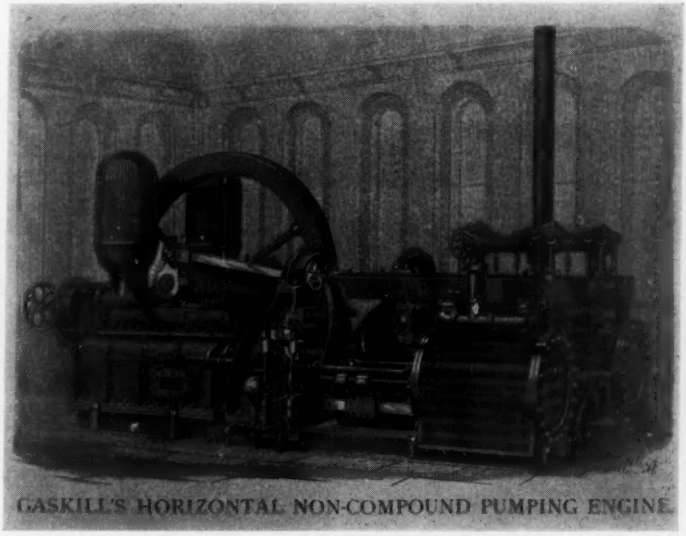
THE HOLLY QUADRUPLEX PUMPING ENGINE.

FIGURE 6.

the Holly Quadruplex Pumping Engine (Fig. 6), the first of the crank and flywheel type to attain general popularity. This design had four steam cylinders inclined at an angle of 45 deg. and four pumps, one of which was in a direct line with each steam cylinder. The first installation was a 2-m.g.d. unit at the Dunkirk, N. Y., waterworks.

This type was built in a capacity range from 2- to 6-m.g.d. and immediately became popular, superseding previous designs. It was possible, by an arrangement of valves on the steam end, to operate all four steam cylinders, which were of the same diameter as a "simple" quadruplex engine, or as a "compound" unit, by exhausting the steam from one high-pressure cylinder into the three other steam cylinders, providing a cylinder ratio of 1:3. In this way, suitable propulsive force for either fire pressure or the lower, domestic water pressure could be obtained. The economy due to the use of an increased number of expansions was available for domestic service which prevailed probably 95% of the time. A number of quadruplex pumping-engine installations are still in use as reserve units.

The Gaskill Type of Pump, 1882. The success of the Quadruplex type, encouraged the design in 1882 of a pumping engine known



GASKILL'S HORIZONTAL NON-COMPOUND PUMPING ENGINE.

FIGURE 7.

as the Gaskill, horizontal, compound, condensing type, less costly than the quadruplex, better adapted for pumping larger quantities of water, and occupying the top rank in steam economy. The first installation was a 5-m.g.d. unit at Saratoga Springs, N. Y. The Gaskill engine was built in ten sizes, ranging from 18- to 48-in. stroke, with a capacity range for the different sizes, from 1 to 20 m.g.d. A large number of Gaskill installations was made in the period between 1882 and 1906.

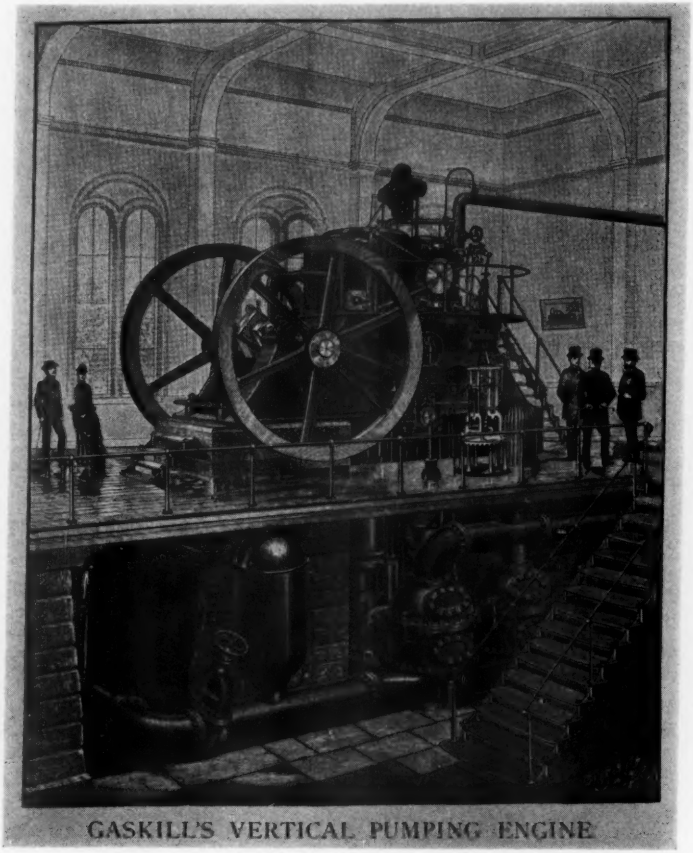


FIGURE 8.

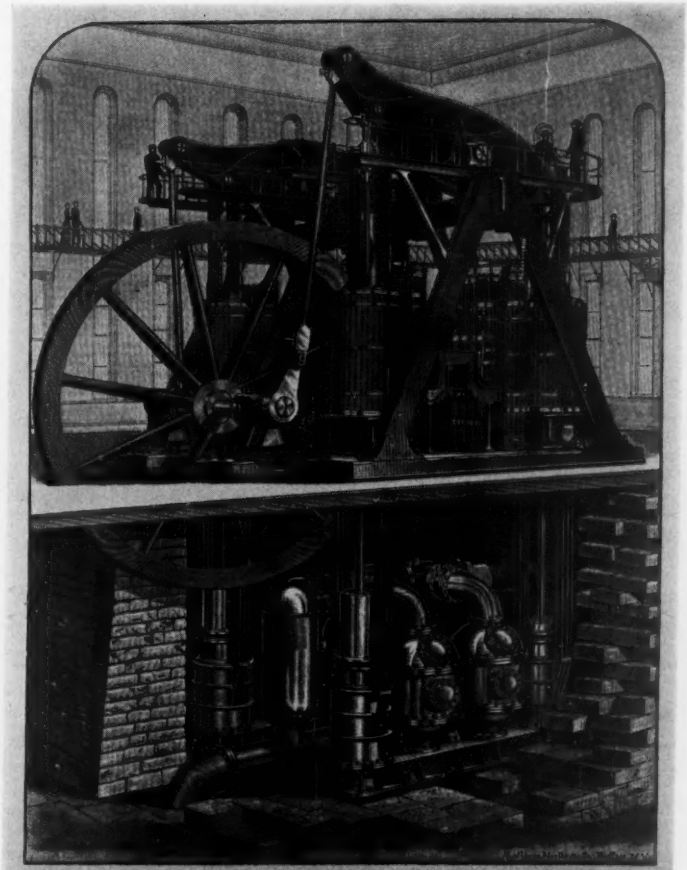


FIGURE 9.

Opposed-Type Horizontal Cross Compound Crank and Flywheel Pumping Engines. A later modification of the Gaskill type was the opposed horizontal cross compound crank and flywheel engine which reduced the number of steam cylinders from 4 to 2, reduced the number of working journals from 26 to 6, and allowed considerable increase in steam economy. This opposed-type engine was built in

capacities from 2- to 20-m.g.d. In 1922, the city of Memphis, Tenn., purchased two opposed-type crank and flywheel engines, each rated 15-m.g.d. and 200-ft. head and, under the same contract, bought two turbo-centrifugal pumping-units for the same conditions of service. Further reference to these Memphis units is made under "Geared Turbo-Centrifugal Units" (Fig. 17).

As late as 1929, installations of the opposed type were made at the plants of the Cambridge, Mass., Water Works and of the Shenango Valley Water Co.

The Vertical Triple-Expansion Crank and Flywheel Pumping-Engine, 1886-1914. In 1886 appeared the first, vertical, triple-expansion, crank and flywheel pumping-engine, installed in Milwaukee, Wis. This type, with its greater possibilities in the way of number of expansions and its relatively small space requirement, allowed it to compete on an evaluated basis to advantage with the latest type of horizontal pumping-engine.

Representative installations of improved-design vertical, triple-expansion flywheel engines around 1897 were three 35-m.g.d. units at the Chestnut Hill Station, Boston, Mass., and a 20-m.g.d. unit at the Spot Pond Station, Boston, Mass. In 1907 and 1914, a total of seven vertical triples were installed by the Cincinnati, O., Water Department. In 1908, at the Lardner's Point Station, Philadelphia, Pa., were installed 12 vertical triple-expansion engines with an aggregate capacity of 240 m.g.d., this being the largest installation of water works pumping-engines in the world. By 1914, the vertical, triple-expansion, crank and flywheel type, in the opinion of many, was the American standard, high-duty, large-capacity, water works pumping-engine.

Ascendency of the Flywheel Type of Engine over the Direct-Acting Engine, 1905. Around 1905 the crank and flywheel type had gained the ascendency in the water works field, and direct-acting pumping-engines were relegated to use as auxiliaries. As boiler practice advanced, steam pressures increased, and superheat was introduced into water works plants, crank and flywheel pump steam cylinders, fitted with Corliss valves, followed the rising steam temperatures to a maximum of 550° F.

Limitations of Pumping Engines. From a commercial standpoint, influenced by the decreasing demand, it was not practical to extend the sizes of horizontal, cross-compound, crank and flywheel

FIG. 10.—THE WORLD'S LARGEST INSTALLATION OF WATER WORKS PUMPING-ENGINES.

units beyond 600 water horsepower, and 20-m.g.d. capacity. These horsepower and capacity conditions correspond to a total water pressure of approximately 75 lb. per sq. in., and a 60-in. diameter low-pressure steam cylinder, having a 42-in. stroke.

In the vertical, triple-expansion, crank and flywheel type, the practical limits were 1200 water horsepower and 40 m.g.d., which corresponds to a total water pressure of 75 lb. per sq. in., together with a 110-in. low-pressure steam cylinder, having a 66-in. stroke.

Within the limits set forth, the economy of vertical, triple-expansion, crank and flywheel type pumping-engines still somewhat exceeds that of the most modern, steam-turbine-driven, centrifugal units. However, their exceedingly high first cost results in a price spread compared with steam-turbine-driven centrifugal units that much more than offsets the slight advantage to the vertical, triple units, from the standpoint of economy.

Nineteenth Century Centrifugal Pumps. The development of the centrifugal pump is definitely identified with the application of power to the pump shaft. As the prime mover has developed, so has the centrifugal pump. As early as 1818, there was developed in the United

States a centrifugal pump with a fairly modern type of casing, but with a paddle-wheel impeller. In 1846, a centrifugal unit was developed having a closed-type impeller with the vanes curving backward.

Early Centrifugal Pumps, 1900 to 1917. By 1900, manufacturers of pumping machinery in the United States were becoming increasingly interested in the centrifugal pump. Many of the earlier units were for special services that gave them considerable prominence, including 24-in. and 36-in. machines for the St. Louis Exposition, 48-in. pumps for drydock service at the Norfolk and Mare Island navy yards, and 60-in. pumps for service in the rice-irrigation fields of the South. These were low-head units, with pumps of the single-inlet type. Many were steam-engine driven. Several of these earlier units were steam-engine-driven pumps for low-head water works service used in conjunction with reciprocating pumps for the higher-head services.

For higher-head services, multi-stage, double-suction type pumps were developed, many of these electric-motor driven because economical steam turbines were not available. Early examples of multi-stage

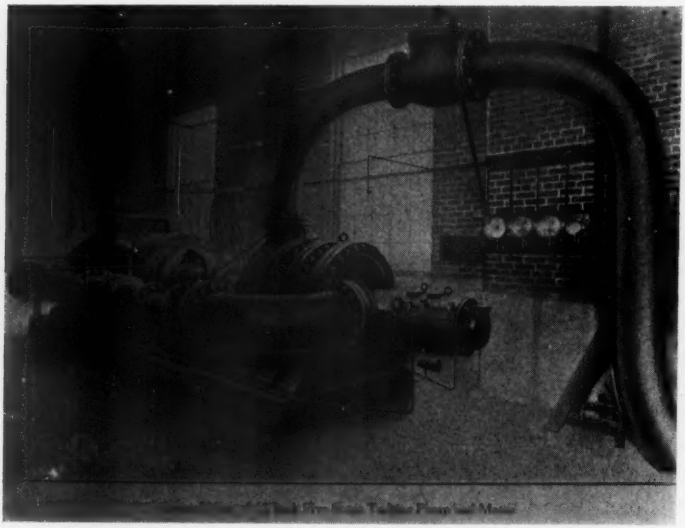


FIG. 11.—12-IN., 5 STAGE, MOTOR-DRIVEN, TURBINE TYPE PUMPING-UNIT INSTALLED IN 1917 AT THE PLANT OF THE BUTTE, MONT., WATER WORKS.

centrifugals for high-head service are the water works units at Athens, Ga., and at Brooklyn, N. Y. Another is the 12-in. five-stage turbine-type pump for the Butte, Mont., Water Works installed in 1917 rated at 4200 g.p.m. at 875 ft. (total dynamic head), driven by a 1300-hp. slip-ring motor at 1180 r.p.m. full-load speed. The motor is of the double extended-shaft type with a two-stage pump at one end and a three-stage pump at the other (Fig. 11).

Around the beginning of the World War period extensive manufacture of centrifugals became the order of the day, to the gradual and final exclusion of other types for general water works service. Developments of suitable drivers contributed largely to this transition. Appropriate coverage of the prime mover must, therefore, accompany any discussion of centrifugal, water works pumping-units.

Comparison of Vertical Triple-Expansion Engines and Centrifugal Pumps at Cincinnati, 1935. A typical comparison between reciprocating and centrifugal pumping-machinery (Fig. 12), is described in an extract from an article appearing in the March, 1935, issue of *Power*.

"A striking example of revolutionary changes in water works pumping practice is found in the main pumping station at Cincinnati, O. There are few places where units for similar duty are contrasted so sharply. Here, beside a row of seven vertical triple expansion reciprocating steam pumping engines, a recently installed horizontal turbine driven centrifugal pump operates under similar steam conditions.

"These triple expansion pumping engines represented the highest development in that class of steam engineering when they were installed in 1907 and 1914 for many years thereafter. Standing approximately 48 ft. high, each with 22-ft. flywheels, they run 20 r.p.m. By contrast, the main elements of the new turbine-driven pump, though nearly three times as powerful as one of the old units, could pass through a 12-ft. pipe. This unit, complete with auxiliaries and interconnecting piping, weighs only 125 tons and looks as if it might be an important station auxiliary, instead of a major base-load pumping unit. However, the 25-m.g.d., 470-ft. head, centrifugal unit develops 2.7 times greater water horsepower, costs only one-quarter as much and weighs one-sixth as much as one of the 25-m.g.d. gal., 175-ft. head, reciprocating pumps. The steam-turbine-driven, centrifugal pumping-unit not only fits steam and water conditions of this long-

established station, but also is readily adaptable to far greater water horsepower outputs and corresponding pump capacities, as well as higher steam pressures and temperatures."

FIG. 12.—25-M.G.D. GEARED STEAM-TURBINE-DRIVEN, CONDENSING, CENTRIFUGAL PUMPING-UNIT AT CINCINNATI, O., ONE OF SEVEN VERTICAL, TRIPLE-EXPANSION PUMPING-ENGINES IN BACKGROUND.

These seven, vertical, triple-expansion pumping-engines at Cincinnati, after upwards of 20 years of service, are still in good operating condition. The city would not be justified in replacing them, neither would it be justified in purchasing additional new equipment of this older type.

Centrifugal Pumps at Detroit. A similar comparison with respect to first cost can be made in the city of Detroit. In 1925, the city purchased a 40-m.g.d., vertical, triple-expansion pumping-engine for $247,000, which is equivalent to $6,175 per m.g.d. capacity. Three years later, for the same condition of service, Detroit purchased two motor-driven centrifugal units having an aggregate capacity of 120-m.g.d. for $50,000. This is equivalent to approximately $417 per m.g.d. capacity. These motor-driven units gave a record-breaking overall efficiency of 84.7% and resulted in the city of Detroit standardizing on motor-driven, centrifugal, water works pumps. The

modernization of the stations of the Detroit Water Works is described in W. C. Rudd's paper of May, 1937.*

Typical Centrifugal-Pump Installations. The present trend towards the use of high-efficiency, centrifugal pumps in water works service is illustrated by two modern 20-m.g.d., 245-ft. total dynamic head, two-stage, centrifugal units, each driven by a 1050-h.p. steam turbine, as well as by four 25-m.g.d., 175-ft. total dynamic head, single-stage, centrifugal pumps installed in 1931, each driven by a 1200-h.p., 720-r.p.m. motor. Both of these installations are in service in pumping plants of the Water Department of the City of New York; the former at the Milburn Station, Baldwin, Long Island (Fig. 13),

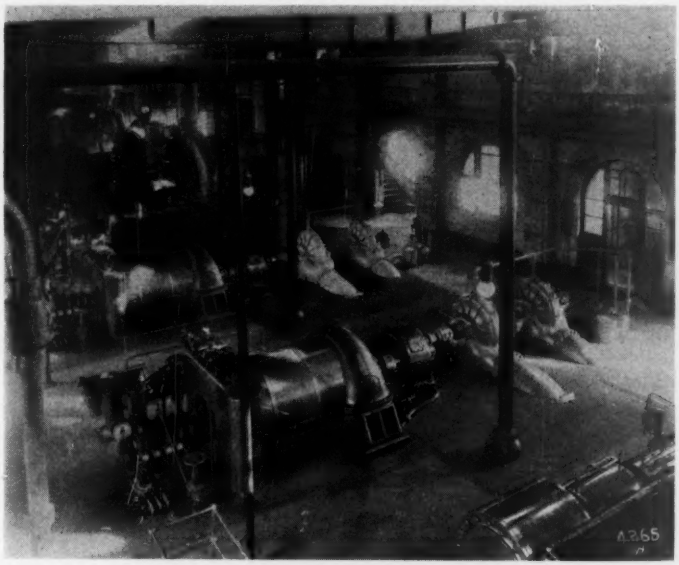


FIG. 13.—TWO 20-M.G.D. GEARED, CONDENSING, TURBO-CENTRIFUGAL, WATER WORKS PUMPING-UNITS INSTALLED IN 1926 AT MILBURN PUMPING STATION, NEW YORK CITY.

and the latter at the Ridgewood North Side Station in Brooklyn (Fig. 14). The centrifugal installation at the Ridgewood Station replaced former large, vertical, direct-acting pumps. A large number of municipal and private water companies have similarly modernized their equipment.

*Transactions, A. S. M. E., pp. 297-312.

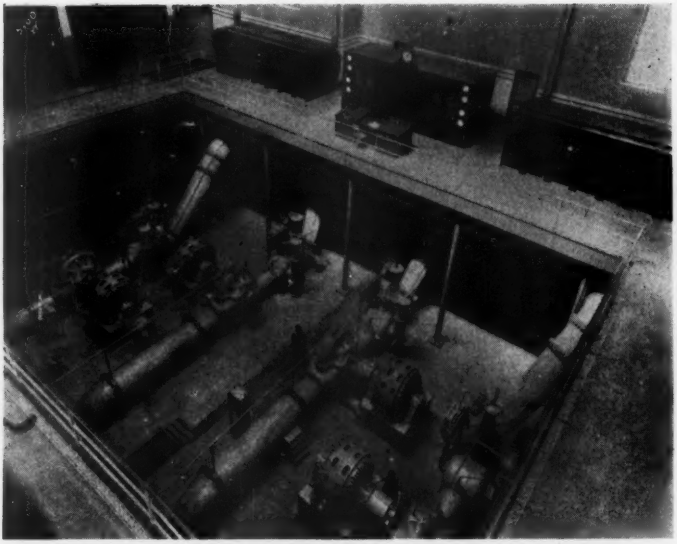


FIG. 14.—FOUR 25-M.G.D. SYNCHRONOUS-MOTOR-DRIVEN CENTRIFUGAL PUMPING-UNITS INSTALLED IN 1930 AT RIDGEWOOD PUMPING STATION, NEW YORK CITY.

Geared Turbo-Centrifugal Pumping-Units. Geared, steam-turbine-driven centrifugals began to receive favorable consideration around 1911 and eventually became a favored type of water works prime-mover, reaching the height of its popularity around 1925. Some manufacturers were quicker than others to realize the advantages of the geared turbine. Some, having heavy investments in plant equipment for manufacturing large reciprocating machines, continued to favor the latter over the centrifugal, all of which coincided with the natural conservatism of water works personnel who as a class favored slow-speed equipment for 24-hour per day water works service. It was soon evident that the geared, steam-turbine-driven, water works pump was here to stay, particularly after early objections to erratic and noisy operation of gears had been overcome.

For a period of a few years, the steam turbine was the most successful prime mover for high-pressure water works pumps. Beginning around 1926, however, the synchronous motor, which had been developed as a highly efficient machine, began to give severe compe-

tition to the steam turbine for water works service and with increasingly lower rates for electric power, motor driven units have since predominated.

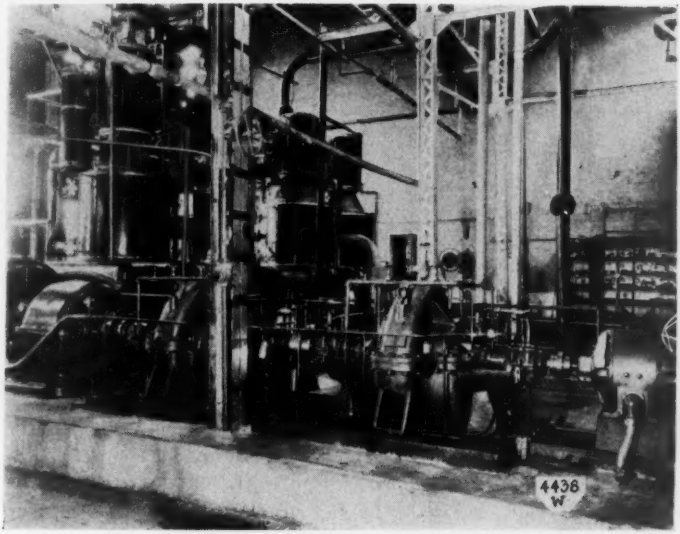


FIG. 15.—COMBINED PUMPING AND GENERATING TURBO-CENTRIFUGAL WATER WORKS UNIT AT ALTON, ILL.

Today, manufacturers report that relatively few inquiries are received covering condensing steam-turbine-driven, centrifugal units for water works service. There are, however, still many existing steam stations where new, steam-turbine-driven, centrifugal units would evaluate in a favored position. Most of the geared turbine units purchased today in horsepowers over 700 are combined pumping and generating machines (Figs. 15-16), some recent examples being the installations at Newton, Mass.; Springfield, Mo.; East St. Louis, Ill.; Chattanooga, Tenn.; and Lexington, Ky.

For units under 600 hp. there is some current demand for geared turbo-centrifugal machines. Recent installations are at Newark and Lorain, and by the Hackensack, N. J., Water Co. A modern, steam-turbine-driven, centrifugal unit is usually equipped with a power-plant-type condenser often with a circulating pump direct-connected

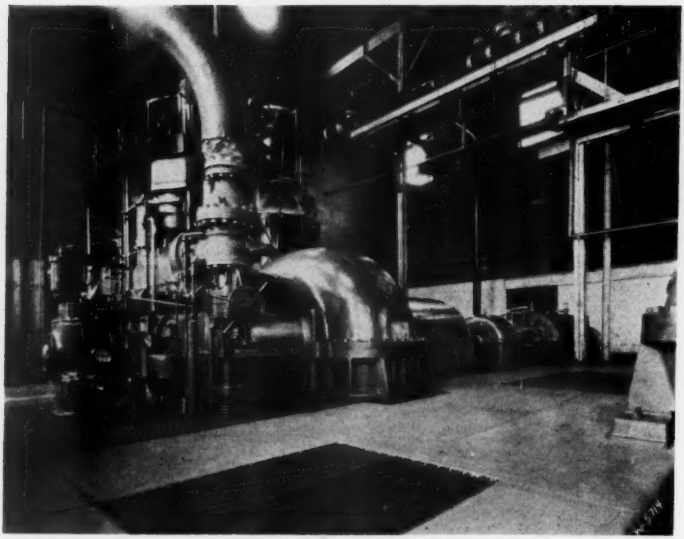


FIG.. 16.—COMBINED PUMPING AND GENERATING TURBO-CENTRIFUGAL WATER WORKS UNIT AT SOUTH PITTSBURGH, PA.

from the pump-shaft extension. Where the suction lift is not excessive, and the amount of steam is relatively large for the pumping capacity, the condenser can be located in the suction of the main pump so that all water will pass through the tubes, thus eliminating the necessity of an independent circulator.

Although new steam stations are rare, there will undoubtedly continue to be several requests per year for steam-turbine-driven, water works pumps. Modern steam turbines are especially adapted for use with the higher steam pressures and temperatures encountered in modern boiler plants. While steam-engine-driven units were entirely satisfactory for the lower steam pressures and temperatures, operating difficulties might be expected at higher pressures and superheats. The steam turbine, on the other hand, is able to take advantage of the higher steam pressures and temperatures without operating difficulty and produces power at a low steam consumption per boiler horsepower hour. The use of alloy steel in the turbine casing and of stainless steel blading contributes to trouble-free operation and sustained efficiency.

FIG. 17.—TWO GEARED, CONDENSING, TURBO-CENTRIFUGAL WATER WORKS PUMPING-UNITS AT MEMPHIS, TENN. ALSO TWO OPPOSED-TYPE, HORIZONTAL, CROSS COMPOUND CRANK AND FLYWHEEL PUMPING-ENGINES—ALL 4 UNITS RATED 15-M.G.D. EACH AT 200 FT. HEAD—INSTALLED IN 1922 UNDER SAME CONTRACT.

The approximate improvement in steam consumption due to the use of increased steam pressures and temperatures is illustrated below with the figures under the horsepower columns representing pounds of steam per horsepower hour.

Steam Conditions	500 hp.	1000 hp.	2500 hp.
125 lb., 0 deg., 28 in.	13.10	11.80	11.10
250 lb., 100 deg., 28 in.	11.10	10.00	9.30
450 lb., 600 deg., 28 in.	10.30	9.10	8.40
800 lb., 850 deg., 28 in	8.70	7.60	6.90

As a water works centrifugal pump operates at relatively slow speed, reduction gears are used between the turbine and pump. The art of designing and manufacturing gears has advanced to a point where a quiet, long life is a certainty because of the use of very accurate gear cutting machines, highly accurate hobs assuring true involute tooth form, and the use of alloy steels in the pinion and gear. Improvements in lubricants and the lubricating systems of reduction gears have also done much to assure proper operation.

Motors. During a century of development of water works ma-

chinery, the electric motor has been available as a driver for only sixty years. Today's most popular driver for water works pumping-units over 100 hp. in rating is the synchronous motor and this in its present form has been available for not more than fifteen years.

The present popularity of the synchronous over other type motors is due to the following characteristics:

1. In high-speed ratings, its full-load efficiency is about 2% higher than that of an equivalent-horsepower squirrel-cage motor.

2. In low-speed ratings, its full-load efficiency advances to about 3% over that of the squirrel-cage machine.

3. The power factor of the synchronous motor, generally rated as unity, is superior to that of an equivalent-horsepower squirrel-cage motor whose power factor progressively decreases at lower speeds. Synchronous motors, therefore, are usually applied regardless of horsepower for speeds of 514 r.p.m. and under.

4. Its starting and pull-in torques have been satisfactorily increased without appreciable price increase, so that, today, high-speed synchronous drivers have almost the same starting characteristics as the equivalent squirrel-cage type, and, when the situation demands, the starting characteristics of the slip-ring motor can be obtained.

The squirrel-cage induction-motor is favored for installations below 100 hp. and the slip-ring type for all powers where it is necessary to meet varying conditions of service. The slip-ring motors, however, with varying speed adjustments obtained by the introduction of resistance into the secondary or rotor circuit, becomes increasingly inefficient as the motor is brought below its full-speed operating-condition. The so-called brush-shifting type of motor, although more efficient at partial loads, compares unfavorably with the slip-ring motor in first cost.

Because there is but little call for direct-current motors to drive water works pumps and because alternating current systems are available most anywhere, future research in the motor field of interest to water works engineers will be in the direction of some kind of varying-speed alternating-current motor. The advantage that could be obtained is obvious when it is realized that, on account of system frequency-limitations, there is no intermediate speed rating for induction and synchronous motors between 1800 and 3600 r.p.m.

The most modern consideration for electric motors from the point of view of design is that of quiet operation. For the past 15 or 20

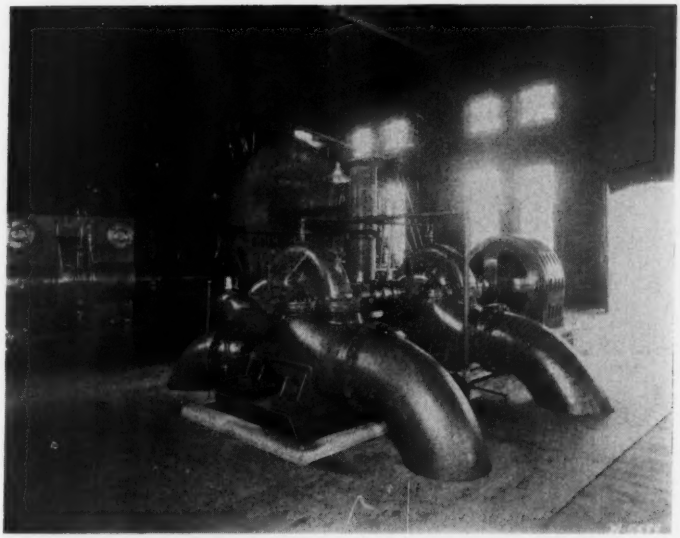


FIG. 18.—18-IN. 2-STAGE CENTRIFUGAL PUMPING-UNIT AT PAWTUCKET, R. I., WITH 800-HP. SYNCHRONOUS DRIVING-MOTOR. CORLISS PUMPING-ENGINE IN BACKGROUND.

years, the public has become increasingly conscious of noise as a factor in motor design, particularly where municipal plants are located near congested business or residential districts. As the size of the motor increases, the necessity for passing large quantities of cooling air through the motor frame gives rise to noises that might become objectionable. There is no nationally recognized standard as to what constitutes a quiet motor, but research now being carried on seems to indicate that continued improvement may be expected.

Diesel Engines. The trend of the past ten years in water works Diesel-engine water works practice has been excellently covered in papers read before the American Water Works Association in 1930 and 1936 by R. D. Hall and W. E. Wechter respectively.

Predictions made in these and in earlier papers have been borne out. The simplicity of the Diesel-driven water works unit with its self-contained power plant, its reliability and flexibility, and its high economy have been fully established. Development of heavy-duty Diesels on a standard production basis has so reduced the cost of

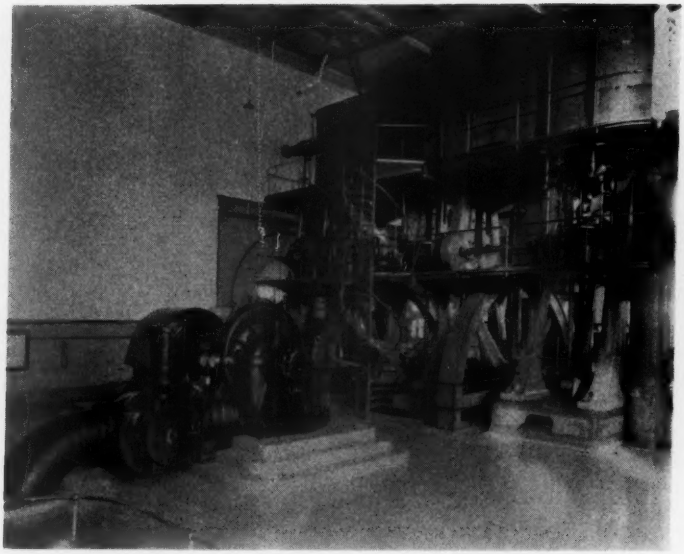


FIG. 19.—24-IN. SINGLE-STAGE, 1750-HP. SLIP-RING-MOTOR-DRIVEN CENTRIFUGAL PUMPING-UNIT RATED AT 35 M.G.D. AT OMAHA, NEB. VERTICAL PUMPING-ENGINE IN BACKGROUND.

this prime mover that in many cases it evaluates better than either steam-driven equipment or purchased power.

From the standpoint of number of inquiries received by the manufacturer, the Diesel engine is second in popularity only to the electric motor as a prime mover for a centrifugal pump. New England, always a leader in the adoption of modern equipment, well illustrates the present-day trend. It has been estimated that since 1934 a total of twenty pumping units has been installed in that section for water works service exclusive of Diesel generators including those which supply power to motor-driven water works pumps.

At the plant of the Milford, Mass. Water Co., the original 100 hp. unit was installed in March 1934, the second, rated 125 hp., in July 1935, and the third, a 180-hp. machine, in December 1937. At Milford, when it was ascertained that the 1901 Snow Holly Steam Pump could no longer be operated, consideration was given both to electric and Diesel power. The first engine was installed against a power rate of slightly under two cents. Results soon established the superiority of

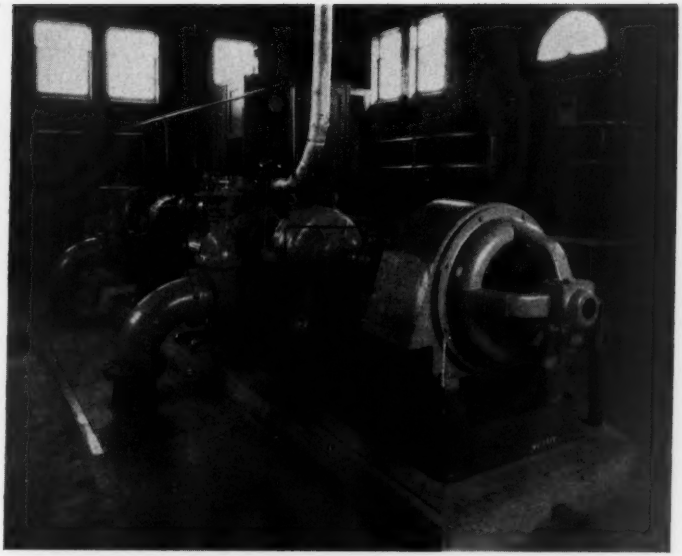


FIG. 20.—UNUSUAL, CENTRIFUGAL WATER WORKS PUMPING-UNIT AT MEDFIELD STATE HOSPITAL NEAR HARDING, MASS.: DOUBLE-ENDED-SHAFT GASOLINE-ENGINE IN CENTER CONNECTED TO A CENTRIFUGAL PUMP AT EACH END AND PUMPS IN TURN CONNECTED TO MOTORS.

Diesels for Milford, and both steam and electricity were abandoned. The 125-hp. unit is operated largely in the summer months when the demand ranges between 1 and 1.1 m.g.d. The 100-hp. machines take care of the winter load of around 0.7 m.g.d., and the 180-hp. unit is retained largely for fire service.

The 250-hp. Diesel installation at the Nashua, N. H., plant of the Pennichuck Water Co. (Fig. 26) is unusual in that it was installed as a standby to a water-wheel-driven Deane and Main plunger pump. Economical operation for two or three months operation was desirable, but the main requirement was satisfactory standby ability to take over the load immediately during the dry season when there would be insufficient water to operate the water wheel.

On two occasions, however, it was necessary to use the Pennichuck Diesel unit during flood conditions, and it proved most satisfactory in that it could be kept on the line and the pumping rate

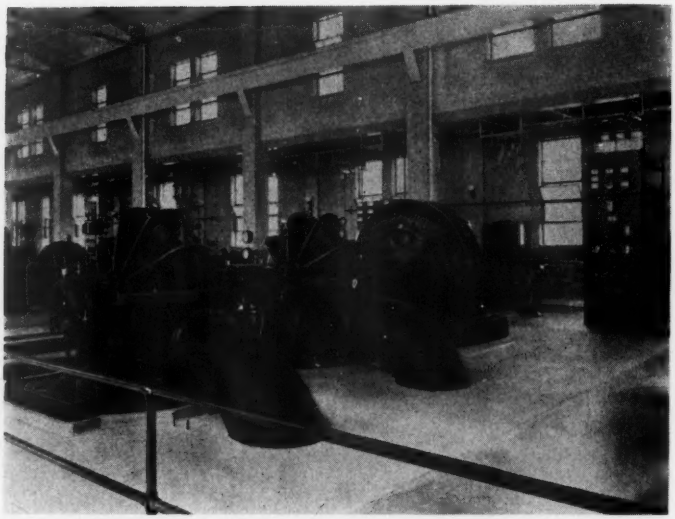


FIG. 21.—24-IN., 2-STAGE SYNCHRONOUS-MOTOR-DRIVEN PUMPING-UNIT AT MINNEAPOLIS, MINN. PUMP RATED 30 M.G.D. AND MOTOR 1600 HP.

FIG. 22.—BATTERY OF MOTOR-DRIVEN, CENTRIFUGAL, WATER WORKS PUMPING-UNITS AT WASHINGTON, D. C.

FIG. 23.—BATTERY OF MOTOR-DRIVEN, HIGH-SERVICE WATER WORKS, CENTRIFUGAL PUMPING-UNITS AT RACINE, WIS.

varied merely by changing the engine speed. This unit has been used for pumping as low as 500 g.p.m. although its normal capacity rating is 6 m.g.d.

A contract was recently placed by the city of Burlington, Vermont, for two 280-hp., 450-r.p.m. Diesel-engine-driven, water works pumping-units. Each unit drives both high- and low-service pumps through the same gear. The decision to purchase Diesels was reached after careful study of the problem by the city and its consulting engineers.

At this point, it is well to mention that in locations where natural gas is available at low rates, the gas engine of similar design to the Diesel offers a very economical prime mover. Gas-engine units driven through gears are already installed at the Wichita, Kan., plant of the Wichita Water Company, and they are a good example of this type of drive. The two units of this type installed therein allow a maximum of flexibility in pumpage over a considerable rate at high efficiency.

For most water works services, Diesel engines are, at the present

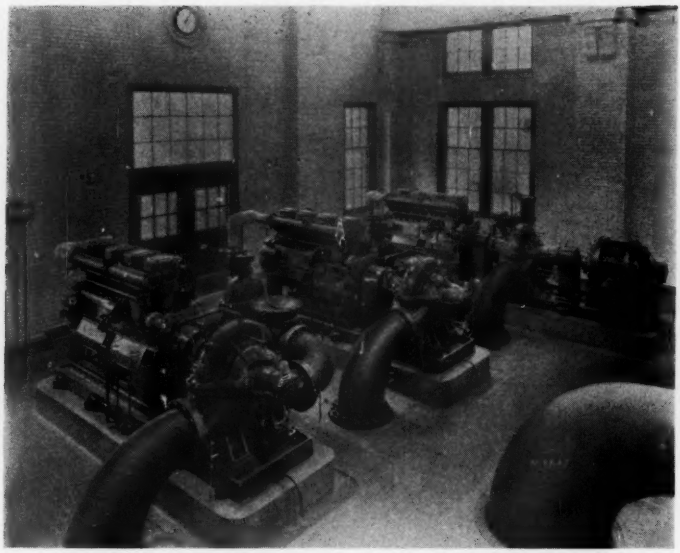


FIG. 24.—BATTERY OF GASOLINE-ENGINE-DRIVEN, HIGH-SERVICE WATER WORKS, CENTRIFUGAL PUMPING-UNITS FOR RESERVE SERVICE AT RACINE, WIS.

time, connected to centrifugal pumps through speed-increasing gears. Engine speeds, however, are increasing from year to year, and manufacturers are constantly engaged in research in ascertaining the means to build engines that will meet the trend toward these higher speeds. Higher speeds would tend to eliminate gears and make these units direct-connected. In Europe, the heavy-duty engine manufacturers have gone a little further than prevailing practice in the United States as regards these higher speeds.

It is not uncommon in Europe to find engines operating at piston speeds of 1500 ft. per min. or more. This trend has not yet been generally accepted in this country, it still being the thought that piston speeds of somewhat under 1200 ft. per min. are about as high as conservative engineering will permit.

Centrifugal-Pump Research. Since 1900, research has been conducted on centrifugal pumps of all kinds, and improvements in design of impellers and later streamlining of the casings have produced efficiencies of 90% in the larger pump sizes. It has often been pre-

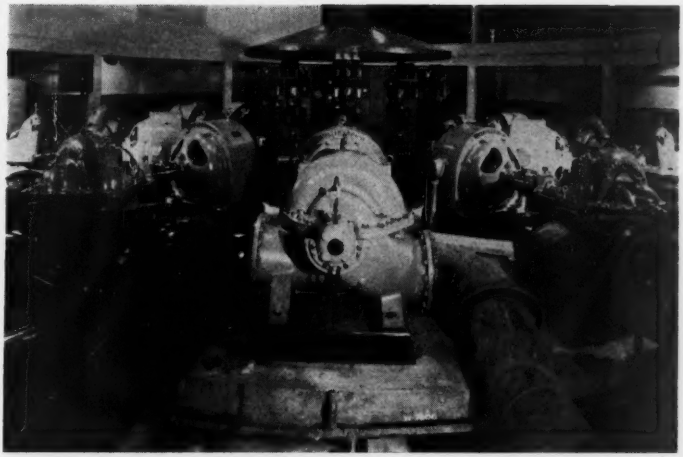


FIG. 25.—BATTERY OF MOTOR-DRIVEN, CENTRIFUGAL PUMPING-UNITS FOR LAGOON AND FOUNTAIN SERVICE AT NEW YORK WORLD'S FAIR—1939.

dicted that but little further improvement could be expected in efficiencies of centrifugal pumps. The development of the pump has kept pace with that of the driver, and the development of the latter has been steadily toward higher speeds. Analytical investigations have proved that the centrifugal pump will yield the highest efficiency when operated at the highest possible speed consistent with the available energy of the suction side.

New and improved types have been developed since the single-inlet centrifugal pump of the early 1900's. Perhaps the first to establish itself permanently in the water works field for the general range of conditions encountered was the double-suction volute. This type allowed substantial increase in the number of revolutions as compared with the original single-inlet design, the double-suction type allowing the water to enter the wheel on both sides, each carrying half the capacity.

Double Suction Centrifugal Pumps. The double-suction type in the water works field is used generally for the pressure range between 15 and 125 lb. per sq. in. For pressures below 15 lb. per sq. in., the double-suction pump is a rather bulky machine; whereas for the higher pressures, over 125 lb. per sq. in., the machine itself becomes smaller but has definite limitations when operating on suction lift.

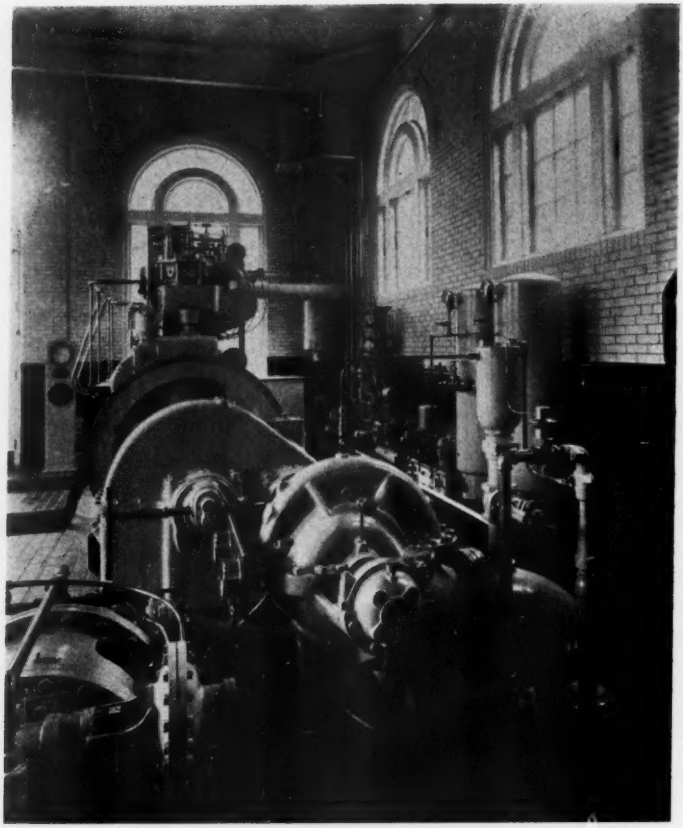


FIG. 26.—PENNICHUCK WATER CO. INSTALLATION—DIESEL-ENGINE-DRIVEN CENTRIFUGAL WATER WORKS PUMPING-UNIT LOOKING FROM PUMP END.

Mixed-Flow Centrifugal Pumps. Some of the later research tests, therefore, have concentrated on the production of pumps suitable for these high- and low-pressure conditions. Several distinct types have resulted that will undoubtedly play an important part in water works pumping in the future for both high-pressure and low-pressure water works machines. For the lower pressure range, say between 10 and 15 lb. per sq. in., a single-inlet volute type has been developed known

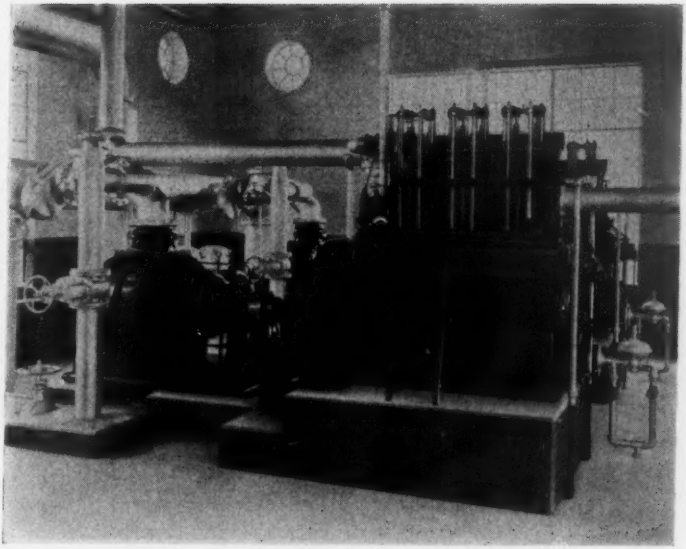


FIG. 27.—ONE OF TWO NATURAL-GAS-ENGINE-DRIVEN WATER WORKS CENTRIFUGAL PUMPING-UNITS AT PLANT OF WICHITA, KAN., WATER CO.

as the mixed-flow pump. This can be equipped with either an open or a closed type of impeller. It is of moderately high specific speed; that is, it operates at higher revolutions than a double-suction pump for the same service. It still retains its ability to lift water 10 or 15 ft. without dangerous cavitation, and its characteristic behavior over a range of heads is illustrated in E-56339 Fig. 28.

This curve illustrates that it is possible to build a mixed-flow pump with a horsepower curve that rises substantially towards shutoff or maximum head condition or with a horsepower curve that remains fairly constant over the whole range, depending on the speed selected. Although definite specific speeds have been stated in Fig. 28, variations in performance using these same speeds could be obtained by changes in impeller design such as the number of vanes employed. The tendency for the horsepower to rise towards shutoff can be suppressed by a lower speed.

Propeller Type of Centrifugal Pumps. Within the past few years, Axiflow and Semi-axiflow pumps have been used for low-head services.

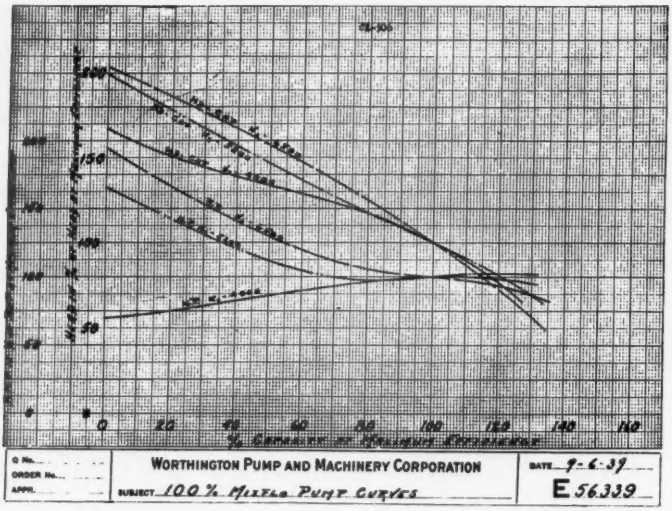


FIG. 28.—CHARACTERISTICS OF MIXED-FLOW PUMP.

These types, sometimes called propeller pumps, have found considerable favor in low-head drainage and flood-control work but are adaptable to any other low-head service, including water works. The performance of the strict propeller-type of impeller, however, is not always suitable for low-head water works service, and it is more correct to use the designation Semi-axiflow. This type, which operates at somewhat higher speeds than the mixed-flow pump, should, on account of its characteristics, be submerged in order to avoid cavitation. It is, therefore, limited to a vertical shaft arrangement. (Figs. 29, 30, and 31.)

The sectional elevation shown in Fig. 29 represents a Semi-axiflow pump designed for operation against a pressure of 15 lb. per sq. in. For water works service, a pump of this type would be equipped with a water-lubricated rubber bearing or with a graphited form of bearing.

Figures 30 and 31 illustrate a type of Semi-axiflow pump suitable for low-head water works service that involves a great variation in river level. The 42-in. pump shown on these two drawings is suitable for a capacity of 45,000 g.p.m. against a differential pressure of 21.5 lb. per sq. in.

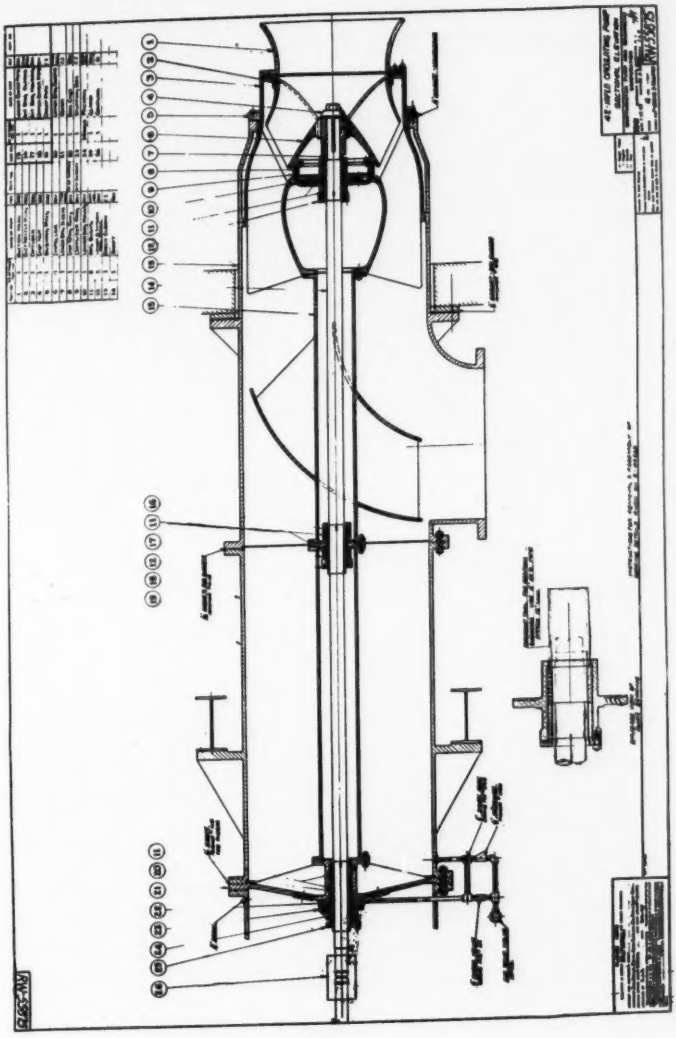


FIG. 29.—SECTIONAL ELEVATION OF 42-IN. SEMI-AXIFLOW CENTRIFUGAL PUMP.

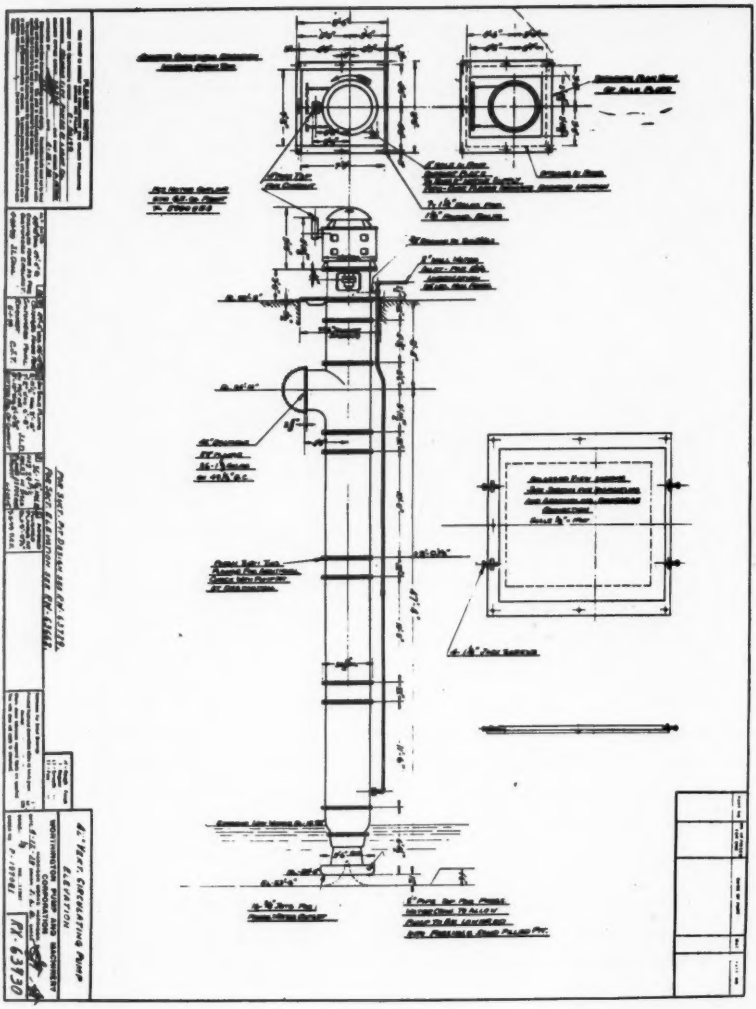


FIG. 30.—ELEVATION OF 42-IN. SEMI-AXIFLOW CENTRIFUGAL PUMP RATED AT 45,000 G.P.M. DIFFERENTIAL PRESSURE OF 21.5 LB. PER SQ. IN.

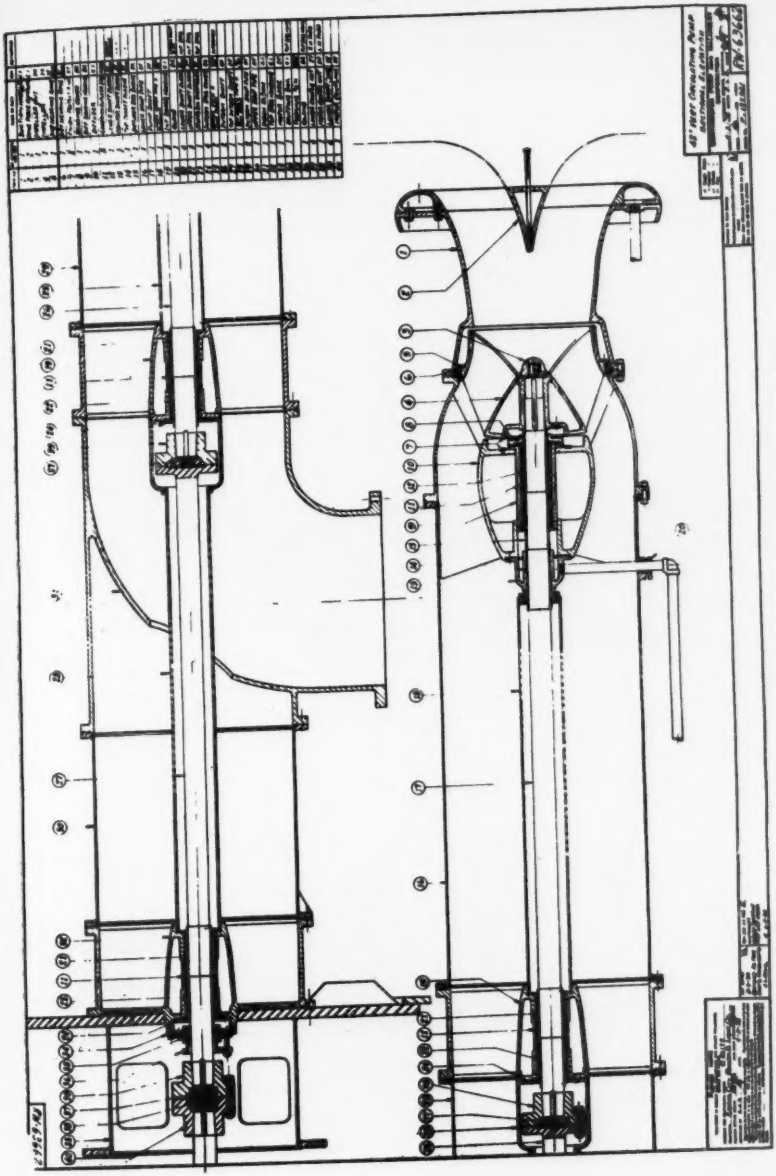


FIG. 31.—SECTIONAL ELEVATION OF 42-IN. SEMI-AXIFLOW CENTRIFUGAL PUMP AS DESCRIBED UNDER FIG. 30.

Standardization of Specific Speed. The Standards of the Hydraulic Institute have defined centrifugal pumps by types and specific speeds. All manufacturers today, therefore, offer fairly standard equipment in the double-suction and mixed-flow types for a given set of conditions, and the equipment furnished should be suitable provided that there are no unforeseen conditions not apparent at the time of the inquiry. Tests are being analyzed, and undoubtedly, in the future, the Semi-axiflow and other types of pumps will be more clearly defined as regards specific speed.

Vertical Bottom-Inlet Centrifugal Pumps. Extensive model testing shows that single-stage pumps can be advantageously used for pressures far in excess of 125 lb. per sq. in. and that the efficiency of such pumps is equal and better than that of two-stage pumps, provided the pump center is placed sufficiently below water level so that the water has sufficient energy to enter the impeller without producing cavitation. All this favors the use of vertical-shaft pumps having

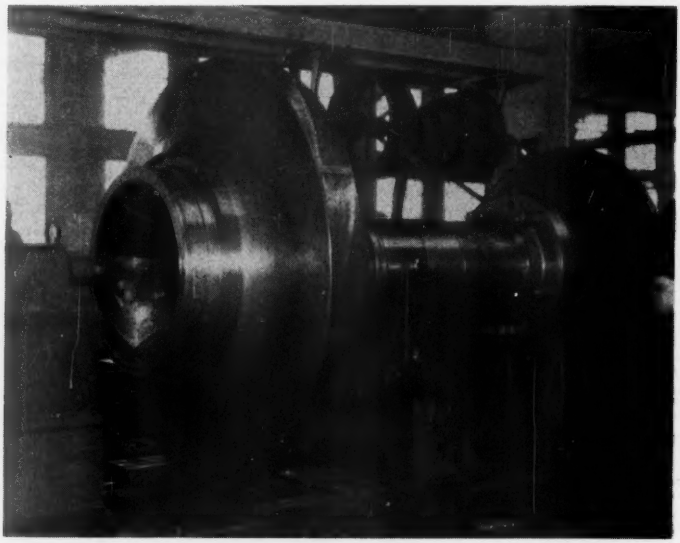


FIG. 32.—42-IN. VERTICAL SINGLE-SUCTION TYPE OF CENTRIFUGAL PUMP-IMPELLER. PUMP RATED AT 200 *c.f.s.* AT 450-FT. HEAD. ONE OF SIX PUMPING-UNITS EACH RATED AT 12,000 HP.—FOR SERVICE ON METROPOLITAN AQUEDUCT FROM THE COLORADO RIVER TO LOS ANGELES.

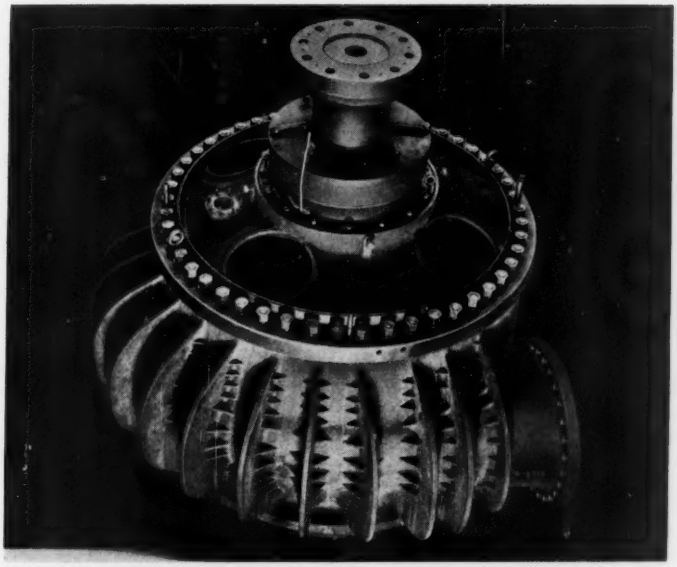


FIG. 33.—42-IN. PUMP CASING FOR ONE OF THE UNITS DESCRIBED UNDER FIG. 32. THESE PUMPS ARE THE MOST POWERFUL EVER BUILT ON THE AMERICAN CONTINENT.

single-suction bottom-inlet type of impellers. It would be impractical to use horizontal-shaft pumps on account of the size of the excavation necessary.

These vertical single-stage pumps resemble the present-day water turbine insofar as general lines are concerned. The accompanying impeller photograph (Fig. 32) and casing photograph (Fig. 33) illustrate a 200-c.f.s. pump for 450-ft. head, which is one of several installed in stations along the Metropolitan Aqueduct that will supply Los Angeles with water from the Colorado River. On account of the very direct water ways and the absence of a shaft through the waterways, this type of pump is most favorable for realizing high efficiency. Earlier predictions that efficiencies higher than 90% could not be expected may have to be revised.

Curve "A" in Fig. 34 shows a model test made in 1936 with 90% efficiency and Curve "B" in Fig. 35 shows a later model test of this type of pump made in 1939 with efficiencies over 92%, which it is

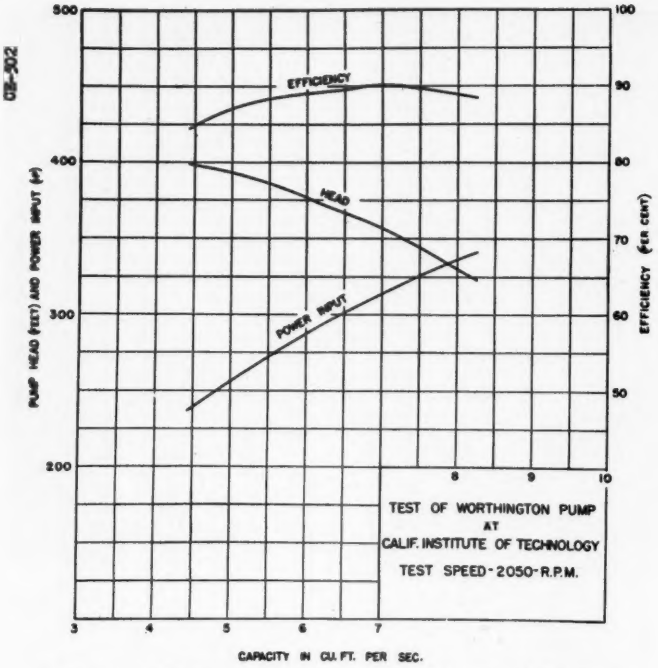


FIG. 34.—1936 MODEL TEST CURVE OF VERTICAL SINGLE-STAGE BOTTOM-INLET TYPE OF CENTRIFUGAL PUMP.

believed to be a record. Curve "C" in Fig. 36, which gives the results of a full-size test of a 54-in. pump for 8,000 hp., shows an efficiency over 91%. Curve "C" pertains to the so-called Rocky-River Pumps installed in 1929 at the New Milford, Conn., plant of the Connecticut Light & Power Co.

In 1938, the Department of the Interior, through the Office of Indian Affairs, purchased two units of the vertical single-inlet type for the pumping plant near St. Ignatius, Mont. Each of these is rated 30,000 g.p.m. at 335-ft. total dynamic head at a speed of 900 r.p.m. The pumps have 30-in. discharge nozzles and 60-in. suction inlets. Each is driven by a 3,000-hp. motor.

The city of Grand Rapids, Mich. recently placed an order for equipment of this type. Five vertical bottom-inlet pumps will be located at Pumping Station No. 1 on the shore of Lake Michigan.

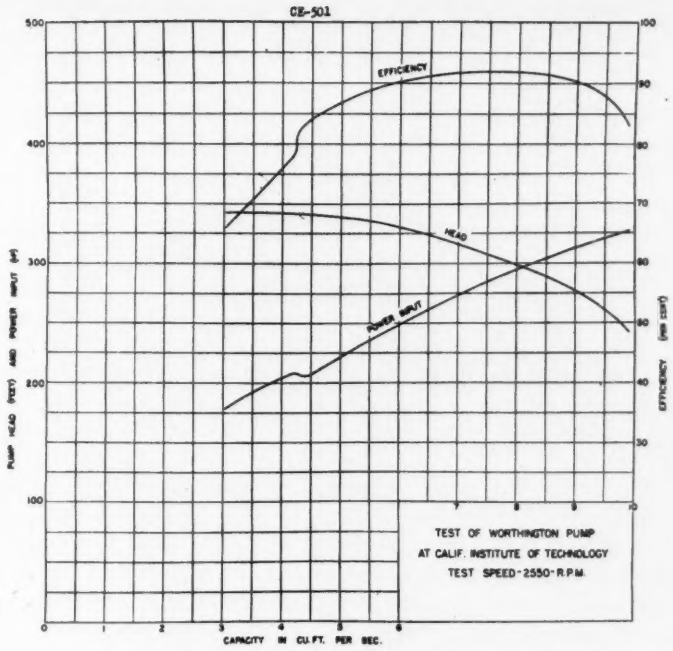


FIG. 35.—1939 MODEL TEST CURVE OF VERTICAL SINGLE-STAGE BOTTOM-INLET TYPE OF CENTRIFUGAL PUMP.

The units vary in power, and range from 700 to 2,200 hp. All units will discharge into a 46-in. pressure line approximately 30 miles long and will form part of a new system that will provide the city with a new source of water from Lake Michigan.

With the proper setting, therefore, pumps for high heads can be made single-stage, provided that the water is reasonably free from grit that might damage running joints and provided, furthermore, that ample provisions are made to counteract eccentric shaft loads that originate in the spiral or discharge chamber of the pump.

Ohio River Type of Centrifugal Pumps. Another interesting arrangement has been produced as a result of the severe floods in the Ohio and other river valleys. With recorded variations of around 60 ft. between flood level and low level it has been necessary to give consideration to means of insuring water supply during flood periods.

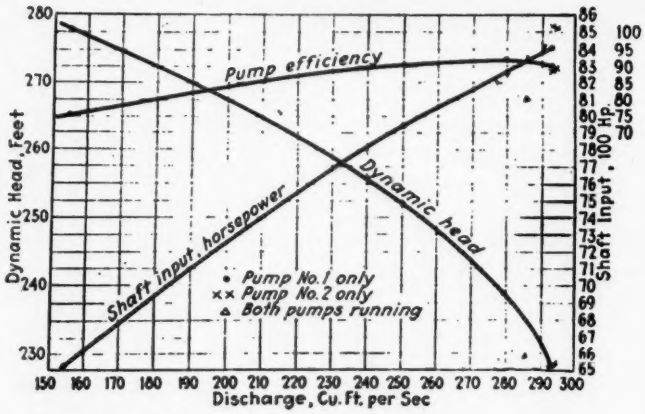


FIG. 36.—1929 FULL-SIZE TEST CURVE OF 54-IN. VERTICAL SINGLE-STAGE BOTTOM-INLET TYPE OF CENTRIFUGAL PUMP.

Out of this has grown a demand for the so-called "Ohio River" type of pump. Installations have already been made at Louisville, Ky., and Evansville, Ind., and other cities along the Ohio River are contemplating equipment of this type. These are vertical single-inlet pumps, single-stage type for heads around 200 ft. with enclosing column-piping to protect the shaft, with the motor beyond high-water level. The distance between pump- and motor-floor levels may be as much as 80 ft.

Conclusion. The science of lifting water has been traced admirably from antiquity to the present times by Walton H. Sears in his paper, read in March 1935 before this Association. The writer has endeavored to avoid repetition of material as given in Mr. Sears' paper while describing the pumping engines and centrifugal units of the past 100 years, and he has given considerable space to present-day trends of centrifugal pumps and their drivers.

The equipping of water works plants with adequate pumping machinery is a field of great interest, involving constant research by numerous manufacturers. Although the centrifugal pump is now the standard water works pump, the particular type as well as the proper prime mover for each contemplated installation demands thorough investigation by engineers in this field. Improved testing facilities, wider use of model pumps, and more skillful interpretation of their test results assure the purchaser of continued progress in water works pumping equipment.

PROCEEDINGS

December 1939 Meeting

Hotel Statler, Boston, Mass.

Thursday, December 21, 1939

President Percy A. Shaw in the chair.

Secretary Gifford announced the election by the Executive Committee of the following members: Russell Starck, Superintendent, Osterville Water System, Centerville, Mass.; John E. McDonald, Superintendent, Water Department, Clinton, Mass.; J. Elliott Hale, Supervising Sanitary Engineer, State Bureau of Health, Augusta, Me.

A paper, "Comparative Studies of Lactose Broth and Brilliant Green Bile with Cambridge Water," was read by Fred E. Smith, Chemist, Water Department, Cambridge, Mass.

A paper, "The Drought of 1939," was read by Harvey B. Kinnison, District Engineer, U. S. Geological Survey, Boston, Mass.

A paper, "Federal Construction Subsidies for Small Public Water Supplies," was read by Samuel M. Ellsworth, Consulting Engineer, Boston, Mass. This paper was discussed by President Shaw, Donald C. Calderwood, Leonard W. Trager, and Francis H. Kingsbury.

January 1940 Meeting

Hotel Statler, Boston

Thursday, January 18, 1940

President Percy A. Shaw in the Chair.

Secretary Gifford announced the election to membership by the Executive Committee of the following: Frank Anthony Nicoli, Assistant Engineer, Metcalf & Eddy, Boston, Mass.; Frederick C. Walton, Foreman, Dedham Water Co., Dedham, Mass.; Frederick F. Aldridge, Senior Sanitary Engineering Aid, Massachusetts Department of Public Health, Boston, Mass.; Madison Hancock Goff, Superintendent, Milford Water Co., Milford, Mass.; Vincent M. Hynes, Division of Sanitary Engineering, Massachusetts Department of Public Health, Boston, Mass.; Scott Keith, Assistant Engineer, Metcalf & Eddy,

Boston Mass. (reinstatement); William Seward Mariner, Metcalf & Eddy, Boston, Mass.

Donald C. Calderwood, chairman of Committee on Emergency Procedures, submitted for discussion a "First Report by the Committee on Water Works Emergencies." This report was discussed by President Shaw, Stephen H. Taylor, Francis H. Kingsbury, Leonard W. Trager, Leland G. Carlton, Harold L. Brigham, Horace L. Clark, and George F. Merrill.

A paper, "Lessons from the 1938 Flood and Hurricane at Ware," was read by George F. Merrill, Superintendent, Water Department, Ware, Mass. The paper was discussed by Francis H. Kingsbury.

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1939-1940

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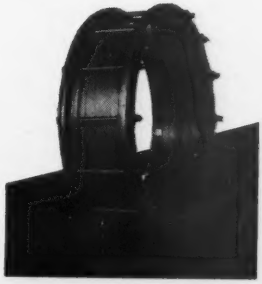

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